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Innovation in a changing world

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Mr. Chairman, ladies and gentlemen,
May I first of all thank TNO very much for their invitation to this conference. The way that the agenda is arranged it seems to move from the more general topics starting this morning gradually to the more and more specific and concrete, especially in tomorrow morning session. I have to confess that personally I would be a bit happier myself talking about more specific and concrete problems tomorrow morning than I am talking about the topic 'Innovation in a changing world' which is a very general topic. I always feel that when people do talk at this high level of generalisation, they often do not do much more than utter platitudes and I hope you will forgive me if I slip into this myself. I shall try to avoid being too platitudinous by being perhaps a little bit more controversial and by trying to relate the generalisations that I will make to at least some empirical evidence from research projects in which we have been engaged.
What I am going to do is first of all to contrast the extreme difficulty of managing innovation at the level of the firm, with the relative succes (from the social point of view) of the social economic mechanism for fostering innovation in industrial societies. Then I intend to discuss some of the reasons for the apparent disillusion with some of the results of succesful technical innovation, and finally, I want to discuss in particular the implications for innovation policy and for technology policy of the recent MIT work on world dynamics and limits to growth.
In my own research I have been especially concerned with the problem of failure in innovation at the level of the firm. Tomorrow my colleague Andrew Robertson will describe some of the results of our project "Sappho" which has been concerned with the study of failure and success.
This preoccupation with failure in innovation is not due to some kind of morbid streak in our personalities and nor is it due to a vein of pessimism. On the contrary we are probably relatively optimistic on many questions of innovation policy. The reason for our concentration on failure is that we believe, first of all that failure is extremely common at the level of the firm - more common than success - and secondly, we believe that failure is extremely instructive. Probably more can be learned from failure than from success, but thirdly at the level of the social system as a whole we believe that the mechanism of failure is an essential part of the evolutionary process of generating succesful innovations. From a social point of view the process is one of survival of the fittest. And from this point of view, failure is a necessary price for a succesful social innovation system. We know now from quite firm empericale evidence what a high proportion of attempted innovations do fail.
Take for example in the United Kingdom the results of the experience of the National Research Development Corporation (the N.R.D.C.). As you all know the N.R.D.C. was established just after the second world war, in the belief that there were many great innovative ideas which for lack of capital and lack of industrial supports failed to make the transition to commercial and industrial application. The idea was, that a government agency sympathetic to inventors - private inventors, university inventors, industrial inventors, and government inventors - would greatly accelerate the rate of introductions of innovations in the British economy. Over the 20 years since its formation, the N.R.D.C. screened about 23.000 ideas which were submitted to it. Of these 23.000 ideas for innovation 5.076 were accepted for further study and examination and lab scale work. Of these, 1.860 became the subject of licensing arrangements. That is already fewer than ten percent of the total submissions. Of these 1.860 only 740 became revenue earning. And here is a gap in the statistics: we do not know exactly which could be described as truly profitable at an appropriate rate of discount on the develop-

ment and investment expenditure. But probably fewer than a hundred could be regarded as commercially succesful, and of these probably not more than ten could be regarded as major successes in commercial terms and one - cephalosporin - is responsible for a very high proportion of the total licensing income of the N.R.D.C. Or another example, take the Batelle Institute. Of 812 ideas selected by Batelle in 1971 for examination, 28 were selected for further support. And of these Batelle estimated that only 2 or 3 would be commercially succesful. They made this estimate in the light of their long experience of innovations since the second world war.

In considering these very high mortality rates for ideas for innovations, it is important to remember that the mortality rate is at its highest at the early stages when ideas are first being sifted. When we come to hardware development and to commercial launch the mortality rate is of course lower. And here we do not have sufficient reliable statistics to go upon. But our experience in the "Sappho" project was that we had no difficulty when considering any succesful innovation in finding several other attempts which were unsuccesful. So that we believe that failure is also a typical feature of the innovation process at this stage of hardware development and commercial launch. And apparently the better management techniques which have been introduced quite widely in American and European industry, have not done very much to offset this high rate of failure. In my personal view, it is probably an illusion to believe that they ever will.

I think that probably Keynes in his book 'The general theory of employment, interest and money' was very near to the mark when he said, as a mathematician and the author of a treatise on probability (one of his first books, before the first world war), that the expectation of success in risky innovation was not based upon a mathematical calculation or probabilities, but rather on animal spirits. There is a famous passage where he compares risky innovations with expeditions to the north pole.

The difficulties of project assessment and of estimating future costs and future markets for innovations are now very well-known. Here we do have an increasing body of emperical evidence which justifies to some extent at any rate Keynes' view of the situation. Take for example the evidence of the Rand Corporation in their study of military systems innovations. It is well-known that the Rand studies showed cost overruns of nearly 3 times the original project cost estimates. At one time it was believed that this kind of very large cost overrun was typical only of military projects. It was thought that because the government was paying and because there was great pressure in terms of urgency of the weapons race, the cost overruns were associated with this particular type of technology. However, we now have further evidence from civil industry that this kind of cost overrun and this kind of margin of error in cost and market estimation is very common also in civil projects. For example, Mansfield in his study of the chemical industry showed that with a number of drug firms cost overruns and time overruns as big as or greater than the Rand findings, were very common.

Similarly we have the evidence from the Manchester business school project on cost overruns which showed that, although they were not quite so great as Mansfield's and the Rand figures, nevertheless cost and time overruns were normal in electricity generation projects. Then we have more recently Olin's evidence for the European chemical industry on the use of project evaluation technique in European chemical firms. We have the evidence of Sunden in Sweden on the use of project evaluation techniques in Swedish industry and we have finally the very interesting confirmation that also in communist countries very big cost overruns are typical. Davis, Amman and Berry have shown that these occur despite the elaborate project evaluation techniques in use in the Soviet engineering industry.

From all this evidence it seems to me that we have to accept what anyone who has been associated with industrial innovation knows quite well, that the margin of uncertainty in innovation is very great, and is likely to remain a major problem for the firm whatever management techniques may be introduced, although they may, I would agree, marginally improve the possibilities of success. For the firm then innovation has been and is likely to remain a hazardous business by definition. However, this does not mean that from the point of view of society as a whole the investment in innovation, however uncomfortable for the firm, has not been an extremely succesful mechanism. On the contrary, the very high attrition rate of failures may contribute to the success of the me-

chanism, seen as a social system. Contrary to Galbraith's assumption of producer sovereignty of giant firms imposing their innovations upon society, our findings in relation to capital goods at least are that it is not possible for a large firm to impose a product, a capital goods machinery or plant innovation on the market and that technically and commercially unsatisfactory innovations do not survive the competitive environment of survival of the fittest which confronts innovators.
The pressure to reduce costs in most branches of industry is so strong that the technically unsatisfactory process or commercially uncompetitive process can not survive in the medium or long run. And this applies also, to small firm industries. And nowhere more for example than in agriculture, the small firm industry par excellence. The United States Department of Agriculture has pointed out that the productivity of American agriculture has risen more rapidly than that of manufacturing industry over a long period. When the first settlers went to the States practically all their time was taken up from sun-up to sun-down in feeding themselves and their families. By the time of the American civil war in the eighteen sixties one American farmer was feeding four other American families. By the time of the outbreak of the First World war in 1914 one American farmer was feeding 8 other American families. Today one American farmer is feeding about 15 other American families and a good part of the rest of the world besides. And a very large part of this sustained continuous improvement in productivity of American agriculture is due to a continuous stream of technical innovations in machinery equipment, seeds, livestock, cultivation methods, fertilizers and so forth.
So that we have had an extremely efficient mechanism for innovation in agriculture, and on the basis of this extremely efficient innovation mechanism it has been possible for the greater part of the employed population to shift out of agriculture into industry and services, and there too, to sustain a very high rate of technical improvement and change. And in the large firm industries, which Galbraith points too quite rightly as the heartland of the American economy, we have had sustained technical change accompanied by very big economies of scale in plant size in such industries as steel, chemicals, electric power, oil refining, paper, plastics and so forth. I would not wish to dispute the advantage of economies of scale in these standard mass-production process industries. So that we have had both in agriculture and in manufacturing industry and increasingly in services, an extremely successful method from the social point of view of generating technical advance. And in my view this method relied fundamentally on innovation in systems, in plant and in machinery - in capital goods above all.
Ironically it was Karl Marx, the most powerful critic of industrialized capital society, who most clearly recognized that the strongest dynamic of industrial capitalism was the innovation system in capital goods. There is a passage in the Communist Manifesto which I think bears quoting at some length because of its relevance to contemporary industrial and technical change. In this passage, written remember in 1847, Marx says:
"The bourgeoisie cannot exist without constantly revolutionizing the means of production. And thereby the relations of production and with them the whole of society. Constant revolutionizing of production, uninterrupted disturbance of all social conditions, everlasting uncertainty and agitation distinguishes the bourgeois of our epoch from all earlier ones. All fixed and fast frozen relations with their train of ancient prejudices and opinions are swept away. All newly formed ones become antiquated before they can ossify. All that is solid melts into air, all that is holy is profaned. And man is compelled to face with his sober senses his real conditions of life and his relations with his kind. The bourgeoisie has brought through its exploitation of the world market a cosmopolitan character to production and consumption in every country. To the great sorrow of reactionaries it has drawn from under the feet of industry the national ground on which it stood. All old established national industries have been destroyed or are daily being destroyed. They are dislodged by new industries whose introduction becomes a life and death question for all civilized nations, by industries that no longer work up indigenous raw materials but materials drawn from the remotest zones from the ends of the earth. In place of the old wants satisfied by the production of the country, we find new wants requiring for their satisfaction the products of different lands. The bourgeoisie by rapid improvement of all the instruments of production, by the im-

mensely facilitated means of communication draws even the most remote barbarian nations into civilization. The bourgeoisie during its rule of scarce one hundred years has created more massive and more colossal productive forces than all preceding generations put together."

Marx was talking about the period from 1747 or 1748 to 1848, that was his "last century". But what he said I think, could apply with even greater force to the period from 1848 to 1948 and perhaps most of all to the last quarter of a century - the last 25 years from 1948 to 1973. From 1948 onwards, the growth rate of the world economy, according to the best estimates of economic historians, has been about double the long term average for world economic growth. Most economic historians estimate the growth rate of the industrialized countries during the nineteenth century at between two and two and a half percent per annum. Some a little faster, some a little slower. It is pretty generally agreed that the growth rate for industrialized countries and for developing countries, in the past 15 years or so has been greater than 4 percent, probably nearer 5 percent per annum. Of course there is the important qualification that population growth rates in the developing countries mean that the per capita increase in national income in developing countries has been a good deal less than 4 percent. But in terms of gross national product, the growth rate has been between 4 and 5 percent for the world economy as a whole, which is nearly double the long term average. The interesting point is, that not only has this growth rate been sustained both in the industrialized countries and in the developing countries, but also both in the communist countries and in the capitalist countries. Contrary to the general feeling in the nineteen thirties, that there were severe problems which would slow down the rate of growth of industrial capitalism, and contrary to the fears of stagnation of the advanced industrial capitalist societies, they have seen in the past 25 to 30 years the most explosive growth and the most sustained period of growth in their history.

There is not much to choose between the growth rates of Japan and the Soviet Union, although Japan has certainly been faster than the Soviet Union; again not much to choose between South and North Korea, or between Mexico and Bulgaria. For every fast growing communist country you can find an almost equally fast or faster growing capitalist country, whether industrialized or an underdevelopped country. This seems to me to show quite clearly that there is a common ingredient, whatever the social economic system in existence in these countries and that common ingredient is of course world technology. Not only do we have the most effective system for distributing the results of innovation through licensing and know-how agreements that has ever been known in the history of the world, we also have the direct transfer of technology through personal migration and movement, and many other means of ensuring that technical advances are rapidly taken up and distributed on a world wide basis. The main way which this takes place is through technology in capital goods - through the improvement in the means, the instruments and systems of production - so that this high rate of technical progress can be sustained only by high rates of capital formation and capital investment.

Yet, at this time of its greatest success when in communist and in capitalist countries, both in industrialized and in developing countries, at this very time the technical innovation and growth ethos has come under the most severe criticism that perhaps it has ever encountered since medieval relationships were first overthrown in this country in England and in other European countries in the 16th and 17th centuries. In 1972 there were two extremely significant events in the United States, the country which more than any other has embodied this technical innovative dynamism of advanced industrial societies. These two events which occurred in 1972, do give, I think, some credence to the believe that disillusion with the results of technical innovation and economic growth is fairly widespread. It is very difficult of course to assess how far there is discontent or dissatisfaction with such a nebulous experience as technical innovation and economic growth. And I certainly believe that social scientists have not yet got means of measuring satisfaction with technical change. So I am only talking about straws in the wind and I am not suggesting that there is any firm evidence on the state of satisfaction (or the opposite) with technical progress. But there were I think two important straws in the wind which do indicate some fairly widespread questioning in the United States of the results, the fruits, of this extremely succesful and sustained process of technical change.

The two events which I am talking about are first of all: the setting up by Congress, a fairly sober body of men, of the Office of Technology Assessment. This has now become law and the office is being set up. This would have been almost inconceivable in the United States before the Second World War. I think it would have been hard to conceive of in the nineteen fifties. And yet the climate of opinion has changed sufficiently that the majority of congressmen, a very big majority, were prepared to set up the Office of Technology Assessment which marks I believe, the end of the idea that technical innovation can simply be left as a successful social process to private industry to get on with it. It is true of course that the O. T. A. will take a long time before it becomes effective. It may never become very effective. It is true also that most innovations will continue as they have before without any formal assessment system through government or any public regulation. Nevertheless a significant number of innovations and potential technologies will now be submitted for systematic public investigation and scrutiny, before they become operative in the United States economy. So that this does mark, I think, at the highest government level a change in the attitude and policies towards technical innovation.

The invisible hand of Adam Smith is no longer regarded as automatically securing the optimum results from the operations of the economy. Some people suggest that it is even become an invisible boot. The nightwatchman state of Adam Smith is no longer sufficient; now the state must be more allseeing and more farseeing more paternalistic and it must watch by day as well as by night, and as far ahead as possible to examine the possible long term consequences of technical change. So this is the first event then, which I think will sooner or later find imitation elsewhere in the world including Europe, the setting up of the Office of Technology Assessment marking a deliberate step towards the public control and regulation of technical innovation.

The second important step which took place in the United States which I believe also was a very significant event, was the publication by Dennis Meadows and his colleagues at the M. I. T. of their book 'Limits to growth' in March 1972 and the subsequent publication of this book in 15 other languages and its worldwide distribution and the very widespread debate which is taking place around that book in this country and in many others.

Although I have made and will make in this talk a number of very serious criticisms of the M. I. T. work, I nevertheless believe that it represents the most powerful and the most important attack on technically oriented economic growth since Thomas Malthus wrote his 'Essay on Population' in 1798. The response to Meadows' book and the debate around it, has shown that ideas of zero growth or of slowing down the rate of growth to a very low rate or even of negative growth as is proposed in the 'Blueprint of Survival' in Britain have taken quite deep root, and are held very sincerely by a great many people, especially of course amongst biologists and ecologists, but also amongst many other professional people including some well qualified to judge these issues, such as Dennis Gabor the Nobel prize winner. So one has to ask the question: Why is it that after the apparent overwhelming success of the technical innovation mechanism both in industrialized and in developing countries, why at this very time do we have this challenge to economic growth and the technical change and innovation upon which their growth is sustained? It seems odd just at the very time when the developing countries are beginning to make that breakthrough to industrialization, and when even India, which was regarded for a long time as the sick joke of development of the underdeveloped world, is beginning to make a real breakthrough in agricultural productivity and in industrialization.

I want to suggest four reasons for this challenge to the ideology and the policy which sustains technical innovation and economic growth. The first two reasons I think are fairly commonplace and will be relatively non-controversial. They are very obvious but I think they are worth stating because they are an essential background to the subsequent argument. First of all it is quite obvious and it was always known to technologists and to economists, as well as to all the religions in the world that there is no direct correspondence between wealth and happiness. It is very obvious, but of course it is something you have to keep all the time in mind. There never was a direct association between increase in per capita income and increase in life satisfaction. I personally believe along with most other economists that it does make it easier to achieve dignity and to achieve satisfaction and happiness in life if one gets rid of brute poverty and has a high standard of living. But they never were the same thing.

As on so many other things Keynes was the best commentator on this point. Not only in his essay on the "Economics of our grandchildren" where he looked forward to new values replacing the struggle for high material standards as societies became more wealthy, but also in the comments he made just at the end of his life when he was retiring from the editorship of the Economic Journal. Keynes became the editor of the Economic Journal already before the First World War, when he was quite a young man, way back in 1913. And he remained the editor throughout his working life until just after the end of the Second World War. When he retired, a banquet was held in his honour and remember this was the time when after a lifetime of hostility to conventional economic policy and a lifetime of struggle against established orthodoxy, his ideas had at last been accepted not only by the economics profession but also by governments, as a necessary method of sustaining full employment and growth. Keynes in his reply to the toast did not say that economists are the trustees of civilization, but that economists are trustees of the possibility of civilization. An extremely important distinction. Keynes throughout his life was a member of the Bloomsbury Group and his closest friends were artists, painters, writers and historians. Books have been written about the Bloomsbury Group and the curious relationship between Keynes, par excellence the man of affairs, the man who had made a fortune on commodity speculation, the man who was the adviser to the government's international organizations, and this bohemian group of artists. It is clear from the history of the Bloomsbury Group that Keynes admired Virginia Woolf, the sensitive writer, Lytton Stratchey, the satirist of the Victorians, Clive Bell and his other artist friends very much more than he admired the more succesful practical money-making people whom he came across in the course of his professional life. For him, art represented civilization. And his activities as a professional economist were directed to the creating conditions for the possibility for that kind of civilization to flourish. That is the first point then, to be quite clear about the difference between material living standards, and civilization and happiness, they are not the same thing although they are related.

The second very obvious point that is also sometimes lost sight off, is what is usually called "The revolution of rising expectations". As long as technical and social change were very slow or non-existent and as long as communications on a worldwide basis were non-existent or very poor then a fatalistic acceptance of poverty was the general rule, it was taken for granted in most countries that very little could be done and ever would be done to improve the lot of ordinary peasants or workers. And as long as this attitude existed, then the hope for improvement was relegated to the hereafter. But once it had been demonstrated that very substantial improvements could be made not just for a tiny favoured minority, but for very large numbers of ordinary people, and once the demonstration effect through mass communications, through air travel, through television, through radio, through all the mass media began to be apparent all over the world, then it became impossible to hold back this pressure for an improvement in living standards for very large numbers of people very rapidly. This is the pressure which leads to the desire of almost all the developing countries for rapid technical and economic progress.

However, once the developing countries began to industrialized, began to succeed with their take off towards improving living standards, you then have the paradox that although they have high rates of growth, the relative rate of improvement has been less than that of the already succesful industrialized countries. The combination of high population growth rates and a low starting point means that although succesful in absolute terms the developing countries have been falling relatively further behind. If you add to this the fact that the effect of importing capital intensive technologies from the West, means that unemployment rates have been increasing rapidly in the developing countries, then you have an extremely explosive mixture of pressure for rapid change, dissatisfaction with the relative level of achievements, and high unemployment rates arising from technical innovation from advanced technologies introduced from the West, largely through multinational corporations. This is a highly explosive situation and it suggests that the problem of inequality is an extremely important one, both worldwide and within countries, when we are considering how to deal with such problems as inflation and world economic development. It could be that a greater spread of equality, a reduction of inequalities on a world basis and within the countries will be a necessary condition for sustaining the acceptance of technical and social change.

These two points are probably not very controversial, but I come now to the two points which are more controversial and which have a greater direct bearing on policy for technology and policy for innovation. The third point I want to make is that the technical innovation mechanism which in my belief has worked extraordinarely well for capital goods, for machinery, for systems, for processes, has not worked quite so well for consumer goods. And I think it is even possible to argue that it worked better for consumers in the 19th century than it has done in the 20th century. Galbraith's idea of producers sovereignty, of firms imposing their ideas on the consumers, is I think rather wide of the mark in relation to capital goods. But I think it is uncomfortably near the mark in a number of consumer goods industries. I want to take only two examples.

First of all take an example which may be an insular peculiarity of the United Kingdom, and if so, I apoligize for this insular example. It is nevertheless an interesting one. In the nineteen fifties and the nineteen sixties about half the housing built in the United Kingdom was built by municipal councils, local counsils subsidized from the central government. This local authority housing was overwhelmingly, flats designed for rent to working class families at relatively low rents. Well, hitherto, up till the nineteen fifties, the general trend in Britain had been to build relatively low rise housing. But in the nineteen fifties high rise tower-blocks of flats became the preferred method for most of the large local authorities, in London, Birmingham, Manchester, Sheffield etc. The blocks that went up began to be 6, 8, 12, 15, 20, 24 story blocks. These became the predominant method of local housing in the late fifties and the early and mid sixties. One would think that a revolutionary change of that character which involved big technical, big economic changes and a big change in the way of life for the families who live in those flats, ought to take place in response to consumer sovereignty, to consumer preference and consumer demand. But the extraordinary thing is, that all the evidence points to the opposite conclusion.

First of all on the straight economics, it has been shown conslusively by Stone at the National Institute of Economic and Social Research and by everyone else who is gone into the economics of the question, that throughout this period high rise flats were more expensive to construct than low rise houses or 3 - 4 story flats. So that all through this period, which I do not need to remind you was a period of extreme economic difficulty for the United Kingdom, a period of continuous pressure on central and local government budgets, a more expensive method of construction of dwellings was adopted than other alternatives that were available within the country. That means that a more expensive technical solution was adopted to a very important problem, which is perhaps the most important problem after food for consumer welfare.

Secondly not only was it a more expensive solution; this might have been perhaps justifiable if there was evidence of strong consumer preference in favour of the more expensive solution, but it was also an unwanted solution. All the sociological evidence indicates that consumer preferences throughout this period remained strongly against high rise flats and particularly amongst working class families with small children. It was only a small minority of the occupants of these dwellings who actually expressed a preference for these high rise flats. When you come to think of it this is an astonishing thing, that in a consumer service which most intimately effects the lives of ordinary people the whole mechanism should apparently operate to the disadvantage of the people who were using those services.

This can be of peculiarity of the U.K., this insular preference for low rise living compared with high rise living and it could be of course that values would change and that people will come to prefer living in 15 of 20 story blocks even in the United Kingdom. But it has not happened yet, and in spite of it not having happened, this solution was

imposed on very large numbers of people. It seems to me, that if that kind of thing does happen against people's known preferences, then it must lead to some degree of discontent and dissatisfaction with the way in which technical progress in the construction industry and in the urban environment works out for the ordinary person.
Secondly take another aspect of technical innovation which again intimately affects very large numbers of ordinary people: so called, perhaps misnamed, consumer durables. Almost everyone who owns a car or owns a television set, and again this may be much worse in the U.K. than elsewhere, knows that one experiences problems over repairs and servicing. One would think it was a relatively simple thing to establish an efficient system of garages and of television and washing machine repairs. But apparently this is very far from the case, and every survey done by the consumers association and other consumer organizations in the U.K., shows that even where there is fairly widespread competition between garages for services to car owners, the standard of servicing of cars is dismally low by any standard of technical or economic performance. This again is rather astonishing, that when you have this terrific success in supplying a range of goods which undoubtedly satisfy people in the sense that they would like to have television, they like to have cars, is accompanied by terrific frustration when it comes to repairing and maintaining these desired goods. This again I think is another cause of discontent with the fruits of technical progress and economic growth.
I could go on with many other examples but time is too short. The point I want to make here is that I believe that there is some evidence that in capital goods the survival of the fittest mechanism operates pretty well, because users of capital goods have got the buying power and the technical sophistication to challenge the suppliers on equal terms. So therefore in capital goods the producers cannot get away with shoddy stuff or with poor technical service for customers. The position is very different in consumer goods because of the disparity in buying power and the disparity in advertising, publicity and in scientific and technical know-how between users and suppliers. No amount of abstract economic discussion can get away from this fundamental disparity. So it seems to me therefore, that the problem of technology assessment in consumers goods and the technology policy design to protect consumers in advanced technical products, is extremely important for all industrialized countries. Although I personally think that Ralph Nader exaggerates his points, I do believe very firmly that the American automobile industry has got what it richly deserved in having Ralph Nader.
I come now to the last point I want to make about the reason for questioning of technical innovation and economic growth, and this relates to the very massive success of economic growth itself. Inevitably when you have got not just a few countries but the whole world economy launched on a path of sustained and rapid economic growth, then doubts must arise about how long this process and this progress can be sustained. Obviously questions arise about depletion of minerals, metals, about depletion of fossil fuels and about the environmental side effects of capital investment and growth of population on this enormous scale. Therefore it is not surprising that when people began to try to work out and extrapolate into the future present day trends of population growth, technical change and economic growth, they came to some rather alarming conclusions.
The best known examples of this speculation about the long term consequences of this continuing process of world economic growth, are the M.I.T. models, the so-called World II model of Forester and its successor the more complicated World III model of Dennis Meadows and his associates, published in the book 'Limits to growth' with the forthcoming technical report which will be published this spring.
We have made at Sussex in the Science Policy Research Unit, a fairly detailed study of both these models World II and World III. We have done hundreds of computer runs to test out the sensitivity of the various assumptions, and to try out the effect of changing some of the relationships. As a result of this testing of these models and as a result of the examination of the assumptions built into these models, we have written a series of 14 papers on the different sub-systems and on the model as a whole, and these are being published in the journal "Futures" and in book form. I do not want to repeat what will be easily available, but simply to single out two main points in our analyses of the M.I.T. work, to show why I think that although we have many points of agreement with the M.I.T. researches, nevertheless in their present form these two world models

would be a bad guide to technology and innovation policy. The main points that I want to make relate to the capital sector and the assumptions made about technical progress. In considering the capital sector, which is one of the 5 sub-systems of the model, it is essential to bear in mind that the model is more sensitive to the behaviour of the capital sub-system than any other sub-system, including the population sub-system.

The behaviour of the capital sub-system is based upon six assumptions about the real world, and in our view none of these six assumptions can be justified either by the empirical evidence relating to 1900 to 1970, or as a plausible logical construction about the likely course of events between 1970 and 2070. So I want very quickly to go through these six assumptions and to say why I think they are not a reliable representation of real world behaviour in the past or likely a real world behaviour in the future. The first critical assumption, made in both World II and World III, is that the average life of industrial capital is 14 years, and this is taken to be a constant right through the period from 1900 to the year 2100. The average life of service capital, which comprises a high proportion of buildings rather than machinery, the average life of service capital is taken to be either 18 or 20 years, a little bit longer than industrial capital. The second important assumption, is that the industrial capital output ratio is also a constant over these 200 years with a value of 3. The third important assumption is, that because the capital output ratio is held to be constant, and because labour is omitted from the model, therefore the assumption is made that there will be no diminishing returns to capital investment in industry, i.e. that technical progress will be sustained in relation to capital goods. Fourthly the assumption is made that the past and future share of sectors, that is agriculture, mining, industry, and services, can be determined in two ways. One by assuming that consumption will be and has been 43 percent of industrial output, a constant over 200 years, secondly that the changes between agriculture secondary activity and tertiary activities can be extrapolated by using cross-country data based on Chenery's work, which means to say that if average world per capita income rises from its present level of about 600 dollars per capita to about 1200 dollars, it is assumed that the distribution by sectors when it reaches 1200 dollars will be that of countries with a 1200 dollar per capita income today. Finally, the assumption is made that the values of the population, that is their preferences between different goods and services, will be unchanged from 1970 to 2100.

We believe that none of these assumptions can be justified by the empirical evidence or as plausible extrapolations of the behaviour of the world to 2100. First of all, take the average life of industrial capital. The model has attempted to build a purely physical model of the world, and their assumption of average life of industrial capital was meant to be about the physical life of capital assets. But in fact of course, the assumption of 14 years is not based upon physical data, it is based upon national accounts data for 1967, and this life of industrial capital is not a physical phenomenon, it is a social economic phenomenon based on depreciation procedures and accounting procedures and commercial obsolescence within manufacturing industry. And to postulate that in the kind of situation envisaged in the next century, of an extreme shortage of capital for all purposes, because of the assumed diminishing returns to investment in agriculture and resources, to postulate that in these circumstances the average life of industrial capital would be a constant unchanged at 14 years, seems to us to be implausible in the extreme.

Secondly the assumption of the industrial capital output ratio with a constant value of 3, is based only on United States data and on no other countries' data. And this again seems to us to be extremely implausible, because all the evidence is that there are considerable variations in the value of the capital output ratio between 2 and 8. And yet the introduction of alternative assumptions about the capital output ratio, produces very different results on the behaviour of the model. If you include the capital output ratio with a value of 4 growth stops all together, if you put in a value of 2 the model would explode and catastrophie would have occured before 1970. So that this extreme sensitivity to a few critical assumptions and the rigidity of all 6 of these critical assumptions assuming constants for 5 out of 6, seems to us inevitably to give the result of explosive growth followed by catastrophic collapse. A more sensitive modelling procedure, which allowed for the flexability of real world social economic variables, would we think give

very different results. In our work we have included alternative assumptions which suggest that the mode of behaviour could then be a gradual approach to limits, rather than explosive growth followed by catastrophic collapse.
My final point is that our disagreement with the M. I. T. work, rests not on the view that we should not make mathematical models in the future, on the contrary we agree with them that such models are extremely important, and better models, we hope, should be built and long term prognostication should be encouraged. We would agree with them that technology assessment of long term changes is essential, but we believe that the assumptions they have built in this particular model are unrealistic and give an unnecessarely gloomy view of the immediate outlook for the next 2 generations. We believe that the physical resources will not constrain the growth of the world economy at least for 2 generations and therefore we would not be prepared to sacrifice the growth of the developing countries in particular with the presently ascertainable risks. But from the long term point of view undoubtedly this kind of model is extremely important and in one form or another, this kind of model building and long term technology assessment must gradually become an ingredient of European technology assessment as well as a worldwide technology assessment system.

DISCUSSION

Question

I would like to bring up the point of housing, which Professor Freeman chose as an example of the failure of consumer oriented innovation. I would have thought that the evidence was overwhelmingly that consumers in Great Britain were not allowed to exert any choice whatsoever in the matter of housing. In fact it was quite simply this, that a local authority imposed this and induced people to occupy them by charging rents well below the market price. I would have thought that, had the market mechanism be allowed to operate, these particular sources of discontent would never have occured.
I think this point is related to the second example of servicing of consumer durables. In fact, I think Professor Freeman indicated something of the true nature of the problem himself, when he said the average consumer did not exert the same sort of buying power as the consumer of industrial capital goods. This is very true, in fact the average consumer is much more concerned with the object, the direct manifestation of his purchase, than with the long term implications of it, as would be, for example, a chemical plant purchaser. The fact is that service is available, but the consumer just does not want to pay for it. And he only finds this out after he has had the object for two or three years. Perhaps Professor Freeman would comment on these two points, in the light of his suggestion that government should play a larger, not a smaller part indicating the future of technological innovation.

Answer

Well, on the point about flats I would agree of course. But the main problem was that the consumers were not able to give expression to their preferences. I don't think it would follow that if there had been no subsidized local authority housing, then the situation would have been better, the conclusion which was suggested. As long as average per capita incomes were rather low, I think there was a very good reason for subsidizing public housing for rent, because if you calculate the proportion of a man's wages which must go on an economic rent, if becomes clear that, if you have a pure market mechanism, then a fairly large group of consumers will have extremely low standards of housing. What I was suggesting was that the mechanism did not work well, but I don't think it follows that a pure private enterprise solution would be the way to solve that particular problem. I would agree that if you introduce an element of public subsidy, then it is very important that this should not lead to the implicit imposition of a public policy against the known wishes of consumers.
I certainly agree that in any case of public regulation or public control, whether in housing or in any other field, an extremely important aspect of that public regulation must be the ascertainment of consumer preferences and consumer wishes.
On the second point about the buying power of consumers in relation to consumer durables. But I believe that here too, an exclusive reliance on the market mechanism would not necessarily give the most desirable results. Just take the case of exhaust-pipes on cars; here the market mechanism has not succeeded in providing the consumer with a satisfactory product.

Stimulation of creativity - Generation of ideas

Professor K. Holt
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I. Introduction

Today, most organizations operate in a dynamic environment, characterized by rapid technological, marketing, economical, political and societal changes. This adds a new dimension to the managerial task. For many managers it is a heavy burden, it may even be a question of survival of the organization. However, for those managers, who are able to respond and capitalize upon the changes, it is much to gain. Those who are able to perceive new needs and utilize technological and social advances, for them there are tremendous opportunities. This is first of all a question of creativity.

II. The concept of creativity

Millions of words have been written about creativity, but our knowledge about the topic is very limited. This is not surprising. Creativity is rather new as a field of scientific study, as shown in figure 1.

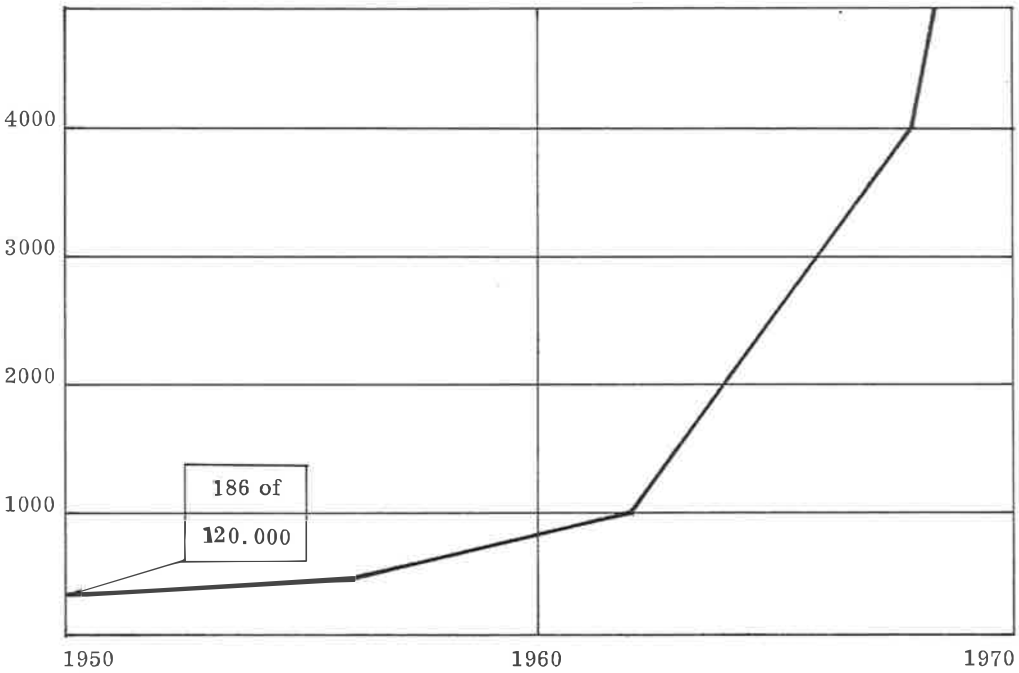

Figure 1. Number of professional papers on creativity

1. Definitions

It is easy to talk about creativity, but it is hard to define. One lacks a commonly accepted all purpose definition. Many persons have tried, but without success. Among the many existing definitions, the two shown in figure 2 are widely used.

CREATIVITY IS	
I. THE COMBINATION OF EXISTING ELEMENTS IN NEW WAYS	II. THAT THINKING WHICH RESULTS IN THE PRODUCTION OF IDEAS THAT ARE BOTH NOVEL AND WORTHWHILE

Figure 2. Two common definitions of creativity

Both definitions require that the result must represent something that is new. The second has a weakness as it depends entirely on a subjective assessment of what is worthwhile. Even with this, it appears to be best for practical purposes. It is action oriented. Creativity is more than imagination. Industry needs innovative ideas - they must be worthwhile - creative thinking must be converted into innovative action. In practice an idea should be considered worthwhile if it is accepted by the person or body concerned for further investigation, for example a feasability study.

2. Theories of creativity

A number of so-called "theories " or hypotheses trying to explain creativity have been presented. Those which are most important from an industrial point of view are shown in figure 3.

I.	THE THEORY OF NECESSITY
II.	THE CHANCE THEORY
III.	THE ACHIEVEMENT THEORY
IV.	THE THEORY OF THE GENIUS
V.	THE THEORY OF SPECIAL GIFTS
VI.	THE THEORY OF THE SUBCONSCIOUS

Figure 3. Some theories of creativity

The theory of necessity states that creative behaviour is motivated by forces outside the individual.
The chance theory claims that ideas are the result of chance occurrences.
The achievement theory assumes that creative behaviour is born out of the desire to accomplish something.
The theory of the genius indicates that creativity belongs to people who have inherited a faculty to create which is not found in other persons.
The theory of special gifts considers some people to be gifted with regard to a certain area such as mathematics, music, etc.
The theory of the subconscious assumes that creative ideas have their origin in previous experiences. The formation of new patterns is the result of uncontrolled processes in the subconscious mind.

All theories are to a certain extent supported by practical cases, but none of them gives a general explanation. It does however appear that the theory of the subconscious has had a great influence on those who have studied the creative process.

3. The creative process

The creative process can be divided in four steps, as shown in figure 4.

I.	PREPARATION
II.	INCUBATION
III.	ILLUMINATION
IV.	VERIFICATION

Figure 4. The creative process

Preparation starts with recognition of a need or the wish to accomplish something. This step also includes some kind of problem definition.
Incubation is characterized by a number of more or less subconscious processes. The matter is dropped for a while and taken up at the subconscious level.
Illumination is characterized by the synthesis and the creation of an idea. The new idea is brought to the conscious plane.
Verification is the last step. Here comes evaluation, elaboration and refinement of the idea.

III. Generation of ideas

Creative ideas are needed throughout the innovation process, which is illustrated with a simple model in figure 5. In real life the process is iterative and highly dynamic with a number of feed-back loops.

The impact of creative behaviour is strongest in the first stage, generation of ideas. This is a crucial point as it starts and gives the direction to the whole innovation process. It consists, as shown in figure 6, of the fusion of a perceived need with the recognition of a technical opportunity.

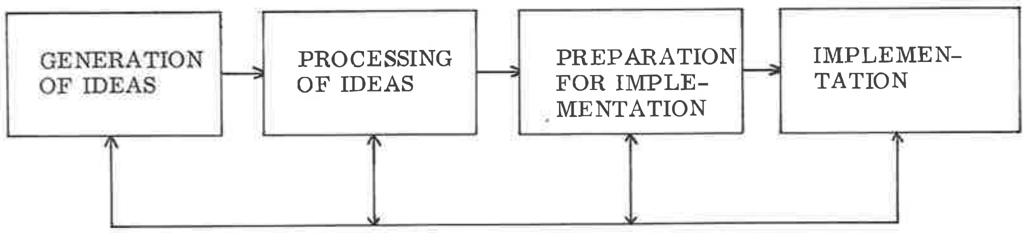

Figure 5. The innovation process

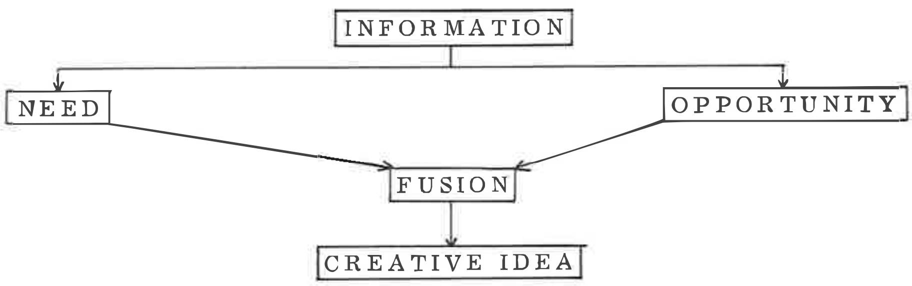

Figure 6. Generation of a creative idea

1. Needs and opportunities

The great majority of innovations are of an incremental nature and start by the perception of a need, as shown in figure 7. Most basic innovations, or the really great advances, are initiated by discovering a technical opportunity.

DISCOVERIES	25%
NEEDS	75%

Figure 7. The importance of the need pull for successful innovations

2. Technical ideas

Although the need perception is important, one should not overlook the technical aspects. Figure 8 shows that ideas for the technical solution of minor innovations originate mostly inside, whereas about two third of the basic innovations come from outside.

MAJOR INNOVATIONS	35%
MINOR INNOVATIONS	65%

Figure 8. Technical solutions originating inside the exploiting company

Although generation and development of good ideas is important, there are other ways of arriving at the technical solution, as shown in figure 9. One can adopt others' ideas and adapt them. A third alternative is to acquire an invention and exploit it commercially.

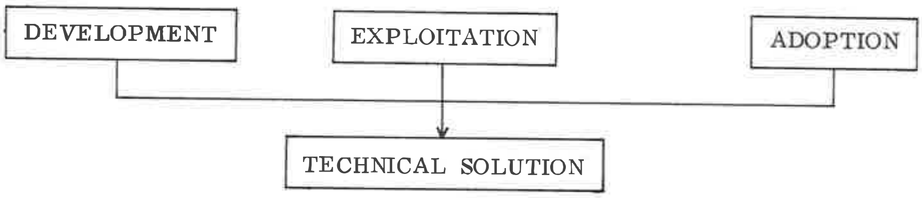

Figure 9. Approaches for finding a technical solution

3. Information input

Most companies are concerned with minor innovations developed inside the company. The information input for this type of innovation is shown in figure 10.

PERSONAL KNOW-HOW	50%
PERSONAL CONTACTS	23%
PRINTED MATERIAL	7%

Figure 10. Information input for finding the technical solution

The most important input is personal know-how, which could be called stored information. Remarkable is the little importance of printed material.

IV. Need for creativity

The first requisite for the stimulation of creativity is the recognition of the need for it. Most organizations today work as open systems in interaction with a dynamic environment. This requires, as shown in figure 11, managers who can handle and improve current activities and at the same time have sufficient innovative and creative capacity to anticipate and hadle the changes.

PAST - UNIMODAL	FUTURE - BIMODAL
IMPROVEMENTS in current products, processes and management system.	IMPROVEMENTS and INNOVATIONS

Figure 11. The future requires a bi-modal firm

During recent years there has been a number of societal changes which have implications for the company. Many people are beginning to question the value of work that gives only money. They have certain expectations with regard to the way they should be treated at work - they require recognition and self-fulfilment through the use of their creative talents.

The capacity of an organization to adapt to a dynamic environment depends on the motivation of its employees. The manager must be aware of human needs and create an organizational climate that allows for self-fulfilment by giving stimulation to independent thinking and creative engagement.

V. Identification of creative individuals

Creative ability appears to be distributed along a Gaussian curve. Of particular importance are those with a very high creative potential. They should be identified and stimulated. Various tests can be helpful here. One weakness is that they tend to measure imagination more than creativity. This is an important, but not sufficient condition for creative behaviour. However, tests are useful because they can indicate individuals with high or low creative potential.

VI. Training in creative thinking and problem solving

Creative behaviour of individuals and groups can be stimulated and improved by various techniques.

1. Analytical techniques

These techniques are based on logical analysis of the problem and its various elements. The best-known is morphological analysis where all conceivable theoretical solutions of the independent variables are listed.

2. Free association techniques

These techniques stimulate the free flow of thought. They are based on the principle that judgement must be suspended and that all ideas should be considered. Quantity is encouraged. The best-known free association technique is brainstorming. It can be applied individually but is normally used by groups. Cross-fertilization, involving the combination and improvement of ideas coming from others is sought. Evaluation is ruled out during the session, but is done thoroughly afterwards.

3. Forced relationship techniques

A forced relationship is established between normally unrelated products or ideas. One of the best-known is the catalogue technique, where two items are picked at random.

4. Eclectic approaches

The various techniques have their spokesmen, but no definite technique can be recommended as a standard approach. One should be taught a variety of creative problem-solving techniques and select those that are most appropriate in each case. This could greatly improve the quality of ideas generated as shown in figure 12.

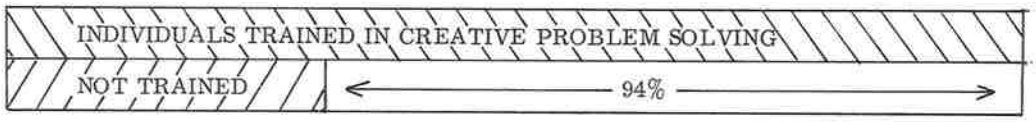

Figure 12. Improvement in the generation of creative ideas through training

In order to use creative problem solving in a company, a sufficient number of motivated key-people from various levels and departments should be trained in the use of the various techniques and act as a core for creative problem-solving groups throughout the organization.

VII. Organizational climate

Identification of creative individuals and training and application of creative problem solving techniques can be a great stimulation for creativity. However, the results can be bad if the organizational climate does not foster creative behaviour. This is a key point in stimulating creativity.

Most companies are organized with the aim of enhancing the effectiveness of the manufacturing, marketing and improvement of current products. This gives the traditional type of organization with clearly defined tasks, rules and procedures, rigidity of structure, and obediance and conformity in the behaviour of employees. Such an organization is not satisfactory in a dynamic environment.

In order to adapt to rapid changes, one must have an organization characterized by speed, flexibility, participation and creativity. Unfortunately, there exists no standard solution. Various approaches may be tried. A more organic management system with departmental differentiation, with interdisciplinary project groups, a certain concentration of innovative functions and various forms of direct employee participation, can, under certain circumstances, be a step in the right direction.

Whichever solution is selected, one thing is the theoretical design, another how it works in actual practice. Often it is useful to assess the impact of the management system on the organizational climate such as it is perceived by the employees*. A method based on 13 factors is shown in figure 13.

I. TIME FOR CREATIVE ACTIVITY	VIII. PHYSICAL ENVIRONMENT
II. FREEDOM FROM RESTRICTIONS	IX. INTERACTION WITH OTHERS
III. FREEDOM OF CHOICE	X. COMPOSITION OF STAFF
IV. RECEPTION OF NEW IDEAS	XI. METHOD OF PROBLEM-SOLVING
V. ATTITUDE OF SUPERVISOR	
VI. ATTITUDE OF THE ORGANIZATION	XII. CONTACT WITH THE PROJECT
VII. RECOGNITION OF CREATIVITY	XIII. TYPE OF PROJECT

Figure 13. Basic factors characterizing the organizational climate

The basic measurement tool is a questionnaire in two versions one for managers and one for staff members. For each climate factor the respondents indicate perceived and desired climate. They also list the three climate factors they find most important and the three of least importance.

A number of climate studies, both in large and small organizations, indicate that the most important factors are "Time for creative activity" and "Attitude of supervisor".

Time for creative activity, i.e. time to communicate with people, read, calculate, experiment and think, is particularly important in connection with the generation of the basic idea, where one has to link old patterns into new relationships. However, when an idea has emerged and is accepted, then the processing of it can often be stimulated by fixing definite time limits for its development and implementation.

Attitude of supervisor and the type of leadership he employs has a great impact on the climate. His willingness to give encouragement and support, his help in the generation of ideas and the way he represents his group, is of great importance. Here is probably one of the most important and difficult tasks facing many managers.

VIII. Stimulation of creativity

Creativity can be stimulated in a number of ways. However, here is a paradoxial situation. Both from an organizational and individual point of view innovation and creativity are strongly needed, but both organizations and individuals fight against it. A basic change in attitude is needed.
Organizations try to protect the status quo. They are designed for efficiency in manu-

* This can be done for diagnostic purposes and for control of the results after changes have been made in order to improve the climate.

facturing, marketing and improvement of current products, resulting in an organization characterized by rigidity and conformity. Individuals have learned to be conformist both in school and at work. This has up to now proved to be satisfactory in a stable environment. However, it does not fit the requirements of an innovative organization. Strong organizational and personal barriers must therefore be broken down. This requires a definite effort from top management which could result in a specific action program for promotion of innovation and creativity. An example of the basic structure of such a program is shown in figure 14.

INTRODUCTORY PHASE
MEASUREMENTS OF ORGANIZATIONAL CLIMATE
PROBLEM DEFINITION
PROBLEM SOLUTION
IMPLEMENTATION
FOLLOW UP

Figure 14. Program for promotion of innovation and creativity

(Time did not permit the lecturer to comment on the program. He therefore concluded by referring those who have a particular interest to the following publication:
Holt, K. The Scanship Case. A program for promotion of innovation.
The International Institute for Management of Technology. Milan, June 1972. 69 p.
which can be ordered from the International Institute for the Management of Technology, 63 Corso Magenta, 20123 Milano, Italia).

DISCUSSION

Question

In talking about discovery push and need pull you said that discovery push is only 20 per cent. I have however the impression that the really big innovations nearly always are a result of discovery push. But even in those cases where discovery push was the prime mover, there must have been some kind of need pull for otherwise the innovation could not have been a succes on the market. So I am in some difficulties about your definitions of discovery push and need pull and I would like to ask you to enlarge somewhat upon them.

Answer

The data I referred to is a simplification of what is going on in real life, which is far more complicated. As an example, let us take the diesel motor. It was developed by Rudolf Diesel, who was an extremely gifted and creative man. During his studies at one of the technical universities in Germany he got his ideas listening to lectures on the theory of the heat engine. There he decided in a very general way that it would be worthwhile to investigate the possibility of constructing a motor based as nearly as possible on the ideal cycle. He was achievement oriented, had an idea and wanted to do somethong. This is an example of discovery push. But at the same time the cities were suffering from smoke, produced by plants with big steam engines and large smoke stacks. There obviously was a need for replacing the steam engine by something else. It is likely that Diesel was aware of this need.

Question

You have given a number of reasons for the necessity of being more and more creative. They were related, I gathered, to the increasing complexity of society and technological growth and you maintained that traditional logic and the analytical approach were not sufficient anymore. Secondly you mentioned that organizing for creativity training gives a big increase in the capacity for problem solving. But even if you take into account an exponential growth in complexity, I simply do not believe that training and organizing is an answer in the long run, and I do think when people feel the complexity of things to be beyond their control, that they turn to creativity training as a panacea and in these cases brainstorming might become a fashionable escape reaction. Could you comment on this ?

Answer

The question gives me an opportunity to stress an important point. People are not alike and uniform. Some people are analytically minded and make great contributions with analytical methods. They experiment, fail, learn and finally get a good solution. So in general I think analytical methods good, and as I indicated there are many analytical methods that appear to be very useful. But you should teach people a variety of techniques and maybe the analytical type can get even better ideas by participating in groups with brainstorming. Of course there are many highly creative people who have done fantastic things without any training in creative problem solving at all and history gives us many instances of that. But if you want to stimulate large groups in organizations to behave creativily, it follows from the data referred to that training in creative problem solving gives results. It must be admitted, however, that it is extremely difficult to measure in practice the correlation between training results and job performance. My conclusion is that if you want to train people in creative problem solving, you should teach them a variety of methods and techniques so that they can use those they find most appropriate.

Comment

Perhaps I can add something to this. At the Batelle Institute at Frankfurt we did a series of studies of creativity techniques and we discovered that we had to distinguish between different types of problems. For a certain type of problem brainstorming gives the best results, for another type morphology gives the most useful results.

Comment

I would like to comment on two points. The first is on the figures you gave about the relatively low influence of the scientific and technical literature on creativity. Then you said that perhaps the information services should be improved or engineers should learn to read. I do not entirely agree with this. In my experience people who read less are more creative and people who absolutely beaver through the literature day after day are better at following up creative ideas which are fed to them. I think the literature is important for communication and for the recording of results which can be used once the basic creative idea has been established.
Secondly, I would like to comment on creativity training. I do agree with the general tone of the remark that has been just made, that creativity training can be a disappointment, but I think that this will only occur if one expects to produce a sausage machine where one puts in an input, turns a handle and expects to get a result. These techniques have to be used with intelligence and with caution. And I take your point about imagination as being a vital part of creativity, but in our creativity training programs we have found that the first signal of the appearance of creativity, particularly with young people in such courses, is the enormous flowering of their imagination, which shows itself not in scientific terms but in artistic terms, drawing, poetry, writing and so on.

Comment

(Holt) I do thank both gentlemen from the audience for their helpful comments, which are, I think, very important for all in management who have something to do with creativity training programs.

Question

I would like to ask another question on discovery push and need pull and about the figures of 30 per cent. and 70 per cent. Do these percentages refer to the number of cases straightaway, or have they been weighted in some way or other by their financial, economical or psychological importance?

Answer

The data referred to can be found in a study by Myers and Marquis (M.I.T.) covering 600 innovations in American companies. They studied incremental or improvement innovations and found that about 75 per cent. were initiated by somebody perceiving a need.

Question

But I do have the impression that the really important innovations, that changed the world in certain aspects, are in the catagory of discovery push. Is that correct?

Answer

Yes, in general it is. Most of the great advances come from highly gifted people, who are achievement oriented and who see a technical possibility and develop it. And I have already mentioned the Diesel motor as a typical example. The study of Myers and Marquis however, covers only incremental innovations, innovations that may be a part of a major innovation. Here too, the Diesel motor is a good example. Originally the fuel was injected by compressed air, and later this was replaced by a fuel pump. This is a good example of an incremental innovation which is a part of a major innovation.

Question

In your lecture you said that the creativity of people falls of after they have reached the age of 30 years. But we all know that there are people who stay creative long after that. Would you comment on this?

Answer

My remark was based on a study made by one man and he did not back it up with any experimental evidence. The study did, however, refer to ordinary people and not to the highly creative. The conclusions of this study may be somewhat exaggerated, but most of us feel that they are rather relevant. When we turn to the highly creative, we have firm evidence that most mathematicians reach their peak between 25 and 30 years and that most natural scientists do so when they are between 30 and 40 years of age. There are instances of people who made highly creative contributions at a higher age, but that does seem to be out of the ordinary.

Management of innovation. The role of communication.

Professor Albert Shapero
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U.S.A.

Man is differentiated from all other creatures by his ability to conceive of new goals, to select from among them, and to create the social mechanism and technologies for achieving the goals selected.
The process of creating and using the results of man's creative efforts has, over the past few years, been described and discussed under the heading of "innovation", which is an omnibus word that is used rather imprecisely.

To avoid some of the confusion that marks the literature on the subject I have chosen to try to define "innovation" in a way that includes the sense, in which it is used by serious scholars in the field as well as the way it is used here to mean the overall process by which invention is brought into being and into successful use by potential users.
The innovation process includes three major and overlapping subprocesses: generation, transformation and diffusion (See Figure 1).
As can be seen in the chart, the overall innovation process consists of three major overlapping subsystems or subprocesses: the knowledge generation subsystems, the knowledge transformation subsystems and the innovation diffusion subsystem.

The knowledge generation subsystem

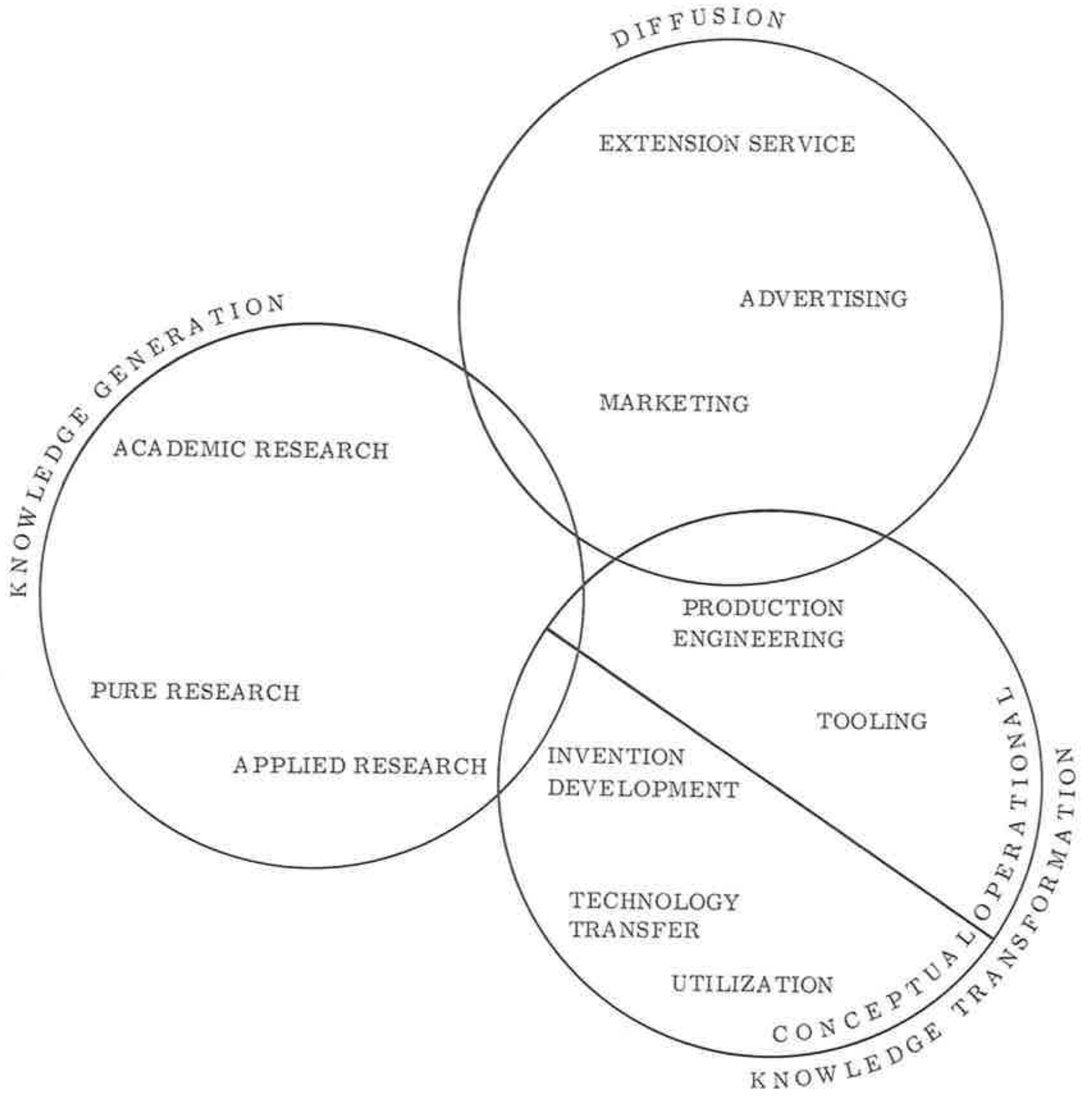
The knowledge generation subsystem is concerned with the generation, storage and circulation of new knowledge. It includes, as far as we know, universities, institutes, laboratories, scientific societies, libraries and the scientific and technical publishing establishment. It includes academic research, pure research, applied research.

The transformation subsystem is devoted to the conceptual and operational transformation of knowledge to use. To bring some collection of knowledge to bear on a problem, opportunity or need almost always requires some transformation from idea to device; from one form of use to another. The subsystem includes development, technology transfer (transfer from use in one context to use in another), technology utilization (transfer from one intended use to another). An innovation must usually go through a final transformation into a form that can be produced and marketed. Thus the transformation system includes such functions as production engineering and tooling.

The diffusion subsystem is a cohesive and coherent follow-on of the transformation subsystem. The diffusion subsystem includes marketing institutions and extension service and also includes a variety of information distribution systems that may or may not be directly connected with marketing in its broadest sense (e.g. advertising, fairs, exhibits).

Management of the innovation process

Management of the innovation process, then, is the conscious, deliberate, intelligent manipulation of resources and conditions to achieve and control the type, quality and quantity of innovation desired. (Control of the innovation process does not only mean obtaining more innovation more rapidly. It also means achieving a desirable decrease in such harmful innovations as dangerous drugs).
Management means the ability to apply our resources and energies to the three subprocesses I have just described, so that we get what we want in terms of utility at the endpoint of the process. The management of innovation includes a large spectrum of activities from the management of academic research to the conduct of industrial fairs. It



THE INNOVATION PROCESS

starts with trying to generate more and better research results or knowledge more effectively and efficiently. It continues with the management of direction, quality and quantity of development and technology transfer, and proceeds through efforts to increase the rate and quantity of acceptance of an innovation by the final users.

Government and industry are interested in many parts of the entire process. It is clear that industry has a vital interest in improving the ability to manage innovation since it is interested in obtaining and maintaining a competitive position in the marketplace. Industry wants new or improved products, new processes that lower costs and prices and new means for providing improved service. Government has a vital interest in managing the innovation process in the interest of improving the social, economic and political position and condition of the nation. Government is interested in innovation for such things as increasing productivity, improving the economy, attaining better health and welfare for its citizens and achieving military security. Today, governments are particularly interested in trying to obtain the transformation of their large investments in research and development, to get more utility from the knowledge produced to date.

Unfortunately, despite a strong public interest in innovation, science and technology there is only a limited amount of empirical information available that is directly applicable to the intelligent management of the innovation process; and if I may be permitted a critical comment, what we have available is not known or is ignored by those who could use it.

I hope you noted, as I did with some interest, that both Professor Freeman and Professor Holt very carefully pointed to the empirical evidence, and I will follow the same approach. The reason we emphasize the data is that we suffer from a pollution in discussions of innovation. The sources of contamination are often the experienced, accomplished, scientists and engineers, who having been successful practitioners, think they can speak authoritatively about the innovation process with no more data than a datum point of one - their own experience.
I would propose that the experience of one man, a single point, is a poor basis upon which to draw a curve.

Two sets of resources are central to every part of the innovation process: people and information, and it is these two sets that are the "materials" which innovation management must operate upon to have any effect on the process. Since people are the producers, adopters and users of innovation their role is obvious and there is a large and familiar literature on creativity, organizational behaviour, social, industrial and marketing psychology that discusses the recruiting, motivating, educating and general treatment of the human in the innovative context.

Not so familiar, and not so well treated, is the importance of information in every part of the process. In one sense, we can make a good case for saying that the management of innovation is the management of information since research and development is really a process of transforming information from one state to another, transformation is an information matching process, and diffusion is certainly a specific communications problems in which we wish to elicit certain behaviors on the part of the receivers of the information that we are transmitting concerning an innovation. The communication of information is the process of transmitting the information from some source to some receiver, and it is the process of communication of the information we loosely identify as knowledge that I want to discuss in some detail.
In the rest of my paper I will discuss some of the relationship of information to each of the three major sub-areas in the innovation process drawing upon available results obtained from a large number of empirical studies from such diverse fields of enquiry as rural and medical sociology, information behavior amongst scientists and engineers, mass communications, the psychology of attitude change, propaganda, diffusion and innovations economics and the history of science and technology. The discussion will be in terms of a one man information system, a two person system, a national and, final-

ly a general information system.
I will examine some of the implications for management of innovation that can be developed from the available information.

The One-Person Information System

The fundamental building block of an information system is the one-person information system. I will discuss the one-person system in terms of man's observed behavior when dealing with the communication of information, and not in terms of his internal psychological makeup. To understand, design, or manage any part of the information behavior relevant to the innovation process we really have to understand something of the way the individual scientist, engineer and manager obtains and uses information; the sources he tends to use, the channels he prefers, the amount of time he spends communicating and the differences between individuals with regard to information communication behavior. Fig. 2 indicates some of the parameters that have been used in emperical studies of information behavior.

Extent of communication and relationship to productivity — First, it is important to know to what extent communication occupies the working life of people engaged in the innovation process. Studies of how scientists, engineers, general and production managers spend their time all indicate that more time is spent in communicating at business, scientific, personal and social levels than all other professional activities combined. In a study of chemists it was found that the average time spent in communication was well over 50% of their working time (33.4% in scientific communication, 10.4% in business communication and over 9% on personal and social communications).

In a series of studies of scientists and engineers in organizations (Pelz and Andrews, 1966) it was found that productivity (as measured by publication of articles, reports and the opinions of peers and supervisors) was generally correlated with frequency of communication with colleagues and outsiders as well as with the number of people communicated with regularly. The more people regularly communicated with and the more frequent the communications the more productivity. The only measure that sometimes went down with frequency of communication was journal article publication. Another study found that journal article production was correlated with the amount of reading done. The more a man reads the more articles he is likely to produce or vice versa.

The idea that a great deal of informal communication is related to productivity goes contrary to the views of traditional managers who have drawn their views from the classical, mass-production ethic. The idea that the coffee or tea break is as important as any activity in the laboratory is difficult for many old line managers to digest. As one man laughingly told me at a seminar in Düsseldorf, his boss agreed that the coffee break was important. He thought that it was so important that he had coffee delivered to every desk so that it would not be interrupted by useless conversation with others.

Sources and channels of information — When examining the use of formal literature, as might be expected, it is found to vary with work situation. Pure scientists make greater use of published materials (75%) than applied scientists (50%). Engineers make almost no use of the so called "good" scientific literature found in the journals. Engineers primarily use handbooks, manufacturers' catalogues, reprints, standards, specifications and research reports. Earlier, when Professor Holt pointed out that engineers do not read the scientific literature, he humorously stated that some people claim that engineers must be taught to read or should be provided with more time to read. I propose that the answer may be that the scientific literature is generally of no use to the engineer.

When the reading behavior of scientists has been compared with that of technologists it has been found that scientists are much more restricted to a narrow band, area-of-work reading interest while technologists browse more, search many areas and read in fields that are peripheral or marginally related to their apparent center of concentra-

Figure 2

The One Person Information System

A. Information	B. Sources	C. Channels	D. Situations	E. Individuals
1. Quantity	1. People	1. Formal	1. Nature of work Pure (R) applied (D) Mgt	1. Capacity
2. Diversity	2. Records	2. Informal	2. Nature of need logistic nutritive	2. Capability
	3. Personal Experience		3. Work setting physical organizational	3. Demographics
				4. Motivation

tion. Technologists or engineers, interested in solving a problem or generating a design that functions are interested in finding any information that will help them with the task at hand. Therefore they are constantly scanning a variety of sources and particularly sources with immediate application to the problem at hand. Scientists are far narrower and deeper in their literature needs, essentially consuming articles as one form of input to the production of new journal articles. The very low use of journal articles by engineers and technologists raises a serious question as to the wisdom of the current and proposed expenditures on expensive computerized retrieval systems to make available to engineers information which they do not use.

As has already been suggested, oral channels, or word of mouth, play a very important place in information behavior in the innovation process. In one study it was found that oral channels were used to acquire necessary information 30% of the time. In another it was found that technologists use oral channels more than scientists. Something of the nature and importance of oral, face-to-face communications is obtained from a very interesting study of the use of various information channels in research and development projects, particularly under conditions of stress (Bodensteiner, 1967).
The latter study compared the use of written, telephonic and face-to-face communication on several projects, particularly during periods of confusion or difficulty. It was found that in each instance of stress there was a buildup in the frequency of telephonic communication followed by a buildup in face-to-face communication until the problem was finished. Written communications were apparently used as a means of putting something on record, but not for the communication of currently needed information. A further observation made during the study was that where organizations had more face-to-face communications on a regular basis there appeared to be fewer periods of stress on their projects.
The results of the research on use of channels suggest that there are characteristic differences between channels that lead to the use of one, the face-to-face, more than another, telephone, and both of the foregoing far more than written communication for important or difficult communications. One important characteristic difference may be in terms of richness; that is the number of symbols available in each channel of communication. In the English language there are about 29 symbols available for use in the written language; 26 letters of the alphabet and three significant punctuation marks. In the spoken language there is something like 49 or 50 symbols available when one takes into account all the forms of inflection, hesitation, vocal urgency and the like. In face-to-face communications the number of symbols available include all of the vocal symbols plus body posture and facial expression. If one writes to a stranger "You are a pig!", he must be prepared to add a very lengthy explanation or be prepared for a very angry reaction. If one says the same words to a stranger on the telephone, but laughingly and with a warm voice, it is a completely different proposition. Finally, if one says the same thing to a man while looking at him, smiling, shrugging one's shoulders, it can become a completely acceptable expression.

It is, therefore, no surprise that difficult concepts, questions involving risk or trust or difficulty, and problems of every kind are far more efficiently communicated face-to-face than by phone, and far more efficiently by phone than by the written word. (For those who heard this address at the Conference it will become obvious that the written "translation" is far different than the spoken version.) When a man wants to order an item that is completely described in a catalogue, a one line telex is sufficient. The item number is sufficient description for the item. In most areas of the innovation process, however, we are dealing with a high degree of indeterminancy, and are forced, therefore, to resort to the richest form of communication available to avoid confusion and error. Similarly, when we are faced with situations of risk or trouble we resort to richer forms of communication in order to avoid misunderstandings that could lead to serious and unwanted consequences.

Found by accident — When asked where important information was obtained, from 18-20% of the respondents in studies of information sources of scientists replied that it was "by accident". It was the book next to the book that they thought was wanted or an article in a journal next to the one that was sought. All of us have had this experience, and it has always seemed rather accidental. The persistence of the order of magnitude of such finds suggests that we are dealing with events that are not quite random. It suggests that the information obtaining process is not linear or as direct as is often assumed in the design of many retrieval systems. Furthermore it suggests that efforts to classify documents of various kinds in too specific and constrained a manner may rob us of the ability to benefit from that percentage of information that has seemingly been obtained by accident or by some process not yet fully understood.

My colleague, Engineer Achille Ferrari, raises an important point in criticism of some of the thinking that has been associated with information theory. He asks dialectically whether, perhaps, the information is in the noise, and that it may be an error to assume that noise is a degradation of signal. This is an interesting question since it suggests that when we have a specific message to transmit mechanically perhaps noise means loss of that signal. However, if we consider each human as someone with a thousand questions perhaps the noise provides an answer to one of the many questions that had not been the subject of the main transmission but valuable nevertheless (i.e. found by accident). If we take the view that each human is a multi-faceted organism dealing with more than one question at a time it is important to consider whether too clean and neat a mechanical system might not remove very important information from the system.

Situations — Situational factors have an effect on information behavior. The nature of the work, the organizational and physical work setting, and the kind of informational needs to be satisfied influence the way information is obtained and the kinds used. As has already been pointed out, research workers have a greater need for the information to be found in scientific journals than do technologists or managers. People with mission oriented problems use different materials and sources than do those with discipline oriented problems.

Whether an organization places a high value on the acquisition and use of knowledge has a distinct effect on the information behavior found within it. When I use the term "high value" I am not referring to the size of the library's budget or the number of people sent to conferences. I mean the kind of signals received by organization members with regards to information behavior. If you have managers who show their disapproval of reading at work, you will lave less reading. I have seen many a laboratory that had an elaborate library system, elaborate lists of people who should get a magazine next, but no one picks one up because the system is not meant to work that way. If the organization sends no one of any importance to technical meetings the signal is very clear to the rest of the people how valued technical meetings are in the organization. If they send only the new young people whom no one listens to, it tells you clearly what they think about the meeting, and going to meetings. This is also true of seminars.
Since I have been a Professor, I find it rather amusing that companies almost never send very important people to seminars, it tells you what they really think about education. I am not sure they are not right, but it is a measure of the reward system in a company, if it sends the junior people to seminars. Incidentally, if they gain anything in the course, no one of importance listens to them anyway. We did some studies of what happens to men who get masters degrees or doctors degrees under company sponsored programs in the United States, and we found that almost 100% of the time they leave the company after getting their degree.

Some studies by M.I.T. staff have reported on the effects of physical proximity on communication of work related material. It was found that the great majority of such communications took place between people whose desks were less than 30 meters apart. I have experimented with this idea when I was a manager of several research groups, and found that changing to location of a man shifts his work related conversations and the particular flow of information in the organization. It has been said that if you put a research department next to a sales department it produces more products. If you put it near a University it produces more articles.

Differences among individuals — There are differences in capacity and capabilities among individuals that must be recognized. The capability and acquired knowledge you have makes a difference as to what information you perceive and use. We know that if you do not understand Swahili, it is useless to send you a message in Swahili. Further, we find some differences in information communication behavior that significantly affect the use of information in any organization. Allen has done the most significant work in identifying and studying what he calls, "the gatekeeper". We have done some work in the field and prefer to call the man "the high communicator".
The high-communicator is significantly different than others in the way he uses and communicates information. If you look at the reading done by people in a laboratory you will find many people who read two, three, four or five magazines, and then there is a man who reads 30 magazines. He tends to be a person to whom others go to for information and who constantly distributes information. The gatekeeper or high-communicator is one who acquires more written information than other people. Furthermore, he constantly receives information from a constant interchange with others. He is also one of the better workers in an organization. Thus, he is a man who reads a lot, does a lot, talks to a lot of people, inside and outside the organization, and has a great variety of sources of information; raising the information level of the entire organization.
Other aspects of individual differences in communication have been studied in the field of diffusion of innovation. For a long time many thought that younger people are more likely to know about an innovation and adapt it or, at least, to have more wide spread sources of information about it early. However, in their excellent book on communication and the diffusion of innovations, Rogers and Shoemaker (1971), reviewing many hundreds of empirical studies, indicate, on balance, the evidence is that there is no age bias in any direction. About 19% of the relevant studies say younger men use more information, 22% say older men use more information and the rest said no measurable difference. The general conclusion is that age is not particularly important. On the other hand, education is important; the more education the more likely he is to use many different sources of information and the more likely he is to adopt an innovation early.
It almost goes without saying that the motivation of the individual is a critical factor in the acquisition and utilization of information in the innovation process. You can design an information system that has a large quantity of information of high quality, and has all of the best procedures and mechanisms for obtaining, storing and distributing information. You can hire men of good education and men who are clearly high-communicators. However, in the end, if the people in the organization are negatively motivated all of your efforts will have been wasted. As the old saying goes "you can lead a horse to water, but you cannot make him drink." All the creativity exercises, all the education courses, all the management techniques fail if there as an organizational climate or a particular supervisory relationship, which makes the man not want to do something with the information. The trouble, or maybe the pleasure, of research on innovation is that we finally are faced with the situation of men who have choice. We cannot design the process so that it ignores man. Much as we might like to avoid man as a nuisance variable we have to come to grips with the fact that man is the generating resource and that he will not use the other resource, information, unless we motivate him well.

The Two-Person Information System

The one-person information system is the basic building block of an information system, and the two-persons information system is the basic building block of a communication system. Communications implies a source, or sender, and a receiver. We know something about two-person information-communication and behavior from a variety of literatures particularly those of the psychology of attitude change, the diffusion of innovation and the use of information by scientists and engineers.

Coding — Coding is essential to the two-person information-communication system's functioning. The two persons in the system must find a common code if they are to communicate, and perhaps the most important feature of the two person system is that both members activily participate in trying to find a common code. The extent to which the transmitter of a message is dependent on the active participation of the receiver can be illustrated by what I call the "Good Soldier Schweik" defense. Imagine trying to transmit a set of complicated instructions to a person who absolutely does not respond, who shows no facial expression, and who never lets you know whether or not be understands what you have said. A reverse example would be a situation where I tell you, "I was driving my car when another car suddenly crossed my path. Quickly I put on my.." You would instinctively supply a word to help complete the message.

Compare the feature of two way coding with a man-machine communication system in which the human is essentially dealing with a passive receiver. The burden is on the human to frame his question in the code of the machine. The man gets no cooperation, or very little cooperation. Sometimes a machine is programmed with very clever terms, but it does not actively participate in framing the question or finding the code.

Source characteristics — The data show that the characteristics of the source of a message have a definite influence on whether the receiver will change his attitude in a given direction or whether he will be more likely to adopt an innovation being urged on him. The authority, credibility, power, similarity and attractiveness of the source are among the characteristics that have been associated with the effectiveness of information transfer.
The more the source of a message has professional or social authority the more the listener or reader is likely to accept and use the information transmitted. Most technical readers quickly check the author's credentials and place of work and the publisher before deciding how to consider the material to be read. Advertisers have long known about the effectiveness of authority. Thus we find advertisements with a man in a white laboratory jackets, signifying science, urging us to use some headache powders.

The more credible the transmitting individual or organization the more likely is the receiver to accept the message. The more the transmitting person fits into the social-cultural framework of the receiver the more his message is acceptable and accepted. The more power the source has over the receiver, in the sense that he can apply sanctions, the more the message is accepted.

The more the source of a message is attractive to the receiver the more likely is the message to be heard and accepted. One of the characteristics that denotes the high-communicator is that the is socially liked, people go to him for information willingly. No matter how many university degrees a man has and no matter how extensive his personal data system, others will avoid him of they have to pay a psychological cost to get information from him. Furthermore, they will be disposed to find reasons to question or reject his information. Men will construct elaborate means for building circuits around the difficult and unlikeable "expert". It is not surprising that the high-communicator is found to be "easy" to approach, a pleasure to deal with.

The two-person bond — I would like to introduce a new concept at this point; that of the two-person bond. Two persons, communicating for the first time, generate a relationship that has a potential for becoming a continuing, value-laden bond between the two. The creation of the bond is dependent on the experience with the initial change and the potential value seen in the relationship. The disappearance or strengthening of the bond is dependent on the number, variety and value of subsequent exchanges. Where you find a growing and continuing relationship you will find a series of exchanges of information intertwined with social exchanges of many kinds; invitations to lecture, recommendations, consulting. Each exchange strengthens the bond. The longer the time between exchanges the weaker the bond, but another exchange (like the electronics "dither") brings the bond to high strength again. Interestingly, I find that the exchanges cannot be on the basis of quid-pro-quo; that is, "I have given you something now you owe me something." Quid-pro-quo exchanges have a one transaction duration, and both parties are quit of each other after each exchange. The bond also carries with it validation of the information transmitted. You accept and trust information sent to you by someone with whom you have a bond. The older and richer the bond the more valid the information.

I have tried simple trials based on the idea that a bond can be strengthened, and become the conduit of highly valued information. I have mailed a paper that I have written to 40 people, randomly selected from my card file of names and addresses in an effort to see what reactions would occur, what pattern they might take. An interesting sequence of reactions followed. I immediately got back letters from some saying "Glad to hear from you," and telling me all about themselves. One or two even read the paper. I know this because by mistake I had sent the paper out without its bibliography, and only one or two noticed it. After a lag of some weeks suddenly I got back research reports of various kinds from people whose work was of interest to me. After some months I suddenly received a call from one of my addresses who asked if he could count on me in a large research project and urgently asking me for the bibliography from my report.

Another simple experiment is one that I recommend that you try. Take three names of people you know from your address list and call each of them. Tell them only that you had been thinking of them, or that you had decided to find out what they have been doing, or tell them some other such innocuous thing. Then note how much information you receive before the call is finished. It is an excercise in reinforcing the two-person bond that carries with it the most valued and useful information you can get.

Man-to-man versus man-machine — Comparing the two-person information system with the man-machine information system, it becomes easier to understand why there is so little use of the latter.

Two-Person System	Man-Machine System
active two way response	passive one way response
two way coding	one way coding
validation	no validation
rich language	non-rich language
personally rewarding in several dimensions	one dimensional reward

The Network

We are all members of information networks or what has been called "invisible colleges" (See Crane, 1972); that is social circles of a professional nature that play a very large role in information transmission. Our information networks are so much part of our everyday life that we are hardly aware of them. Yet they are so valuable to us that some of our most painful and embarrassing memories are those of situations in which we recommended someone into our network who did something bad or stupid or in bad taste.

The network has several important functions that directly or indirectly affect the information-behavior of its members. The network provides early and informal and rapid transmission of information that is generated within or enters any part of the network. The network provides its members with feedback without threat. The network establishes norms and values for its members and thus provides them with solidarity. As has already been pointed out the network also is a validating mechanism.

People within a science network know of research results something like two years before they are formally published. They have seen them or heard of them from colleagues who have asked them for feedback or merely been told of them informally over a drink at a meeting. After all, after an article is completed and submitted to a journal it takes 10 months to three years for it to be published. A book takes longer, and to find something in a library takes longer yet.
To illustrate how a network functions let me state arbitrarily that I can identify the precise information I want in any technical field using from three to five telephone calls. Take for example a question in a field I know nothing about such as the following: "What is known about the costs and benefits of alternate methods of psychotherapy?" Where to start? If I were to ask you how you would start, in almost every case you would answer that you know a Psychlogist (or a friend who knows a psychologist), and you would suggest call him first. So we make our first call to Psychologist A, apologetically tell him of our problem, and incidentally tell him that you suggested calling him.

Having mentioned your name, Psychologist A, who knows you, takes me seriously, tells me he knows nothing of the subject and refers me to Professor B who really should know about the subject. I call B immediately telling him that A suggested that I call. He tells me of the work of C and D, telling me also that C's work is good and is more recent and that D is really quite bad and very dated. Furthermore, he tells me that I am using the wrong terms, and tells me the terms used in the field. I am now able to go to the library or to an information retrieval system and specify exactly what I want. I can repeat the process if I want a double check.

In the example I have found my way into a network starting from complete ignorance. I have used personal references to get from point to point. I have been taught the proper coding used in the network. I have been given validated information which no library does; having been told whose work is good and which work is old. I have not become a member of the network (that would have to come about as a result of my work and personal sponsorship), but I have used it effectively for a single information trace. I could not use it again and again in the same way without becoming a contributor, for it has been found that members of a network who only take from it without contributing are dropped from the network.

The high communicator and the network — The structure of networks in science might be described as a hierarchy of networks in which the lowest level is a high communicator (or gatekeeper) surrounded by a group, feeding into a higher level network of high communicators. The high-communicator actively applies "dither" to the networks, revitalizing the two-person bonds in the system. He is the man who thrusts information upon you, eagerly telling you about work in another field that is relevant to what you are doing.

The high-communicator plays a vital link-up function. He ties his organization into a wider world of information. He brings with him links to an extended family of networks thereby substantially raising the information potential of the organization. Further, he is a pattern recognizer, seeing relationships between otherwise unconnected bits of information, an important creativity function. One of my students (Holland, 1968) measured this characteristic by administering a psychological test, the Remote Association Test of Mednick to a number of high communicators he had identified in a variety of laboratories and university departments finding that the high communicators had significantly high scores on the test.

Implications for Management

Examining the innovation process, the role of information in the process, and the empirical evidence concerning information communication behavior that is presently available, some possibly useful implications for management are evident. For one thing, it becomes evident that national efforts and investments in large formal scientific information systems will not result in more innovations moving through the system more rapidly. The science research sub-system is a rather self contained organism, consuming its own product. It has little connection with other parts of the innovation process, and, by the very nature of its norms and values, there is little hope that it will become more connected with the rest of the process.

The outputs of the science system are research results and theories in the form of referred publications in scientific journals. The man who publishes first gets the Nobel prize, and in American universities the man who publishes most gets promoted. In many fields if a submitted article is accepted, the author pays page charges of about $ 50 a page; thus, the only market for an article is the author. An article is consumed by others in the production of further articles. When you consider that in the United States, alone, we have 500,000 professors you can well understand the forces driving us to a so called "information explosion".

An important gap — An important gap in our knowledge of information-communication behavior exists in the knowledge transformation subsystem. We have insufficient data on how technologists and engineers actually get and use information. We know very little about how information flows or, better, "trickles" from the knowledge production subsystem into the knowledge transformation system. Filling this knowledge gap I believe is important to all our efforts to get a larger return on the very large investments we have made and continue to make in research and development.

Since there is, little evidence that engineers and technologists in the knowledge transformation subsystem read or use the outputs of the science subsystem except what they have learned at the university 10-15 years before. This suggests that we might try to assure that we transfer more and more useful research results to our students when they are in the university since it is probably their last direct contact with the science world.

At the micro level several management implications become evident:

1. Identify and hire high communicators

2. Consciously provide the high communicator with all the information he asks for

3. Consciously arrange for the physical proximity of the people who should be communicating with each other

4. Formally design situations and contexts that will encourage informal exchange among people within the organization and with people outside the organization

5. Provide incentives to elicit the kinds of information behavior you desire

6. Generate communication flow chains that increase the flow of information to those subsequent sources that have authority and credibility and that are attractive to others so that in the subsequent flow the information will have a higher likelihood of being used

References

The research findings discussed in the body of this paper are based on a very large number of sources that are to be found in the growing body of literature on communications among scientists and engineers. I refer the reader to the excellent annual reviews edited by Cuadra and published by Encyclopedia Britannica.

A few of the sources that have been referred to at greater length are given below:

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DISCUSSION

Question

In our firm we have discussed the preference for written information or personal contacts quite often. Of course we know about the American findings that in the U.S.A. almost nobody uses written information. But I still think that there may be a difference between your country and Europe. Perhaps Europeans turn to written information more easily than Americans. As you have lived in the U.S.A. and in Europe, you may be able to settle this question for me.

Answer

In the main you are right, but it is easy to exaggerate the differences. When my colleagues in the States maintain that the situation is very different in Europe, I kindly point out to them that we do live on the same planet and that most Americans come from Europe anyhow. But it is true that there are some basic differences in communication and information exchange on the two sides of the Atlantic. If I may overgeneralize, it is easier to get informal information in the US than in Europe. One reason for it is that we have a more mobile society. Managers don't fool themselves that there is any economic value in secrecy, they may be working in the other company next month. So they brag to each other about their methods, something that is done to a far lesser extent in Europe.

Remark

I would like to take issue with Professor Shapero on this point. Perhaps I may start by reminding you of your statement about the danger of drawing one-point curves, based on the experience of one person. I suggest that now you are doing something similar, which, however, is not necessarily wrong as we all speak from experience. My experience of my American colleagues, with whom we have many useful and pleasant contacts, is that their use of written information is no less than ours, and that our use of verbal inter-personal contacts is no less than theirs. This leads me to the last issue you raised on the scientific literature. You may, I think, be drawing on your own experience again. But the basic scientific literature very frequently supplies a back-up in background information, and that is very important.

Answer

Well, this gives me the opportunity to clear up some misunderstandings. I didn't give you my opinion on the preference for verbal information, I spoke from a body of literature. There have been done scores of user studies by now, and they all give very consistently that the literature is not used very much. This accords with my own experience and satisfies my prejudices, but I did not draw a one-point curve here.
As to the scientific literature, I did not mean to convey the impression that it is not used at all. That would be untrue; it is used, but not to a large extent. In many cases, a man who wants to know something will not look it up himself, he will ask the high communicator. It has been stressed again and again that this is an unsatisfactory situation; the literature is there to be used and it isn't. That is why I said that the information leaks rather than flows. And I have the impression, but I cannot cite any study on it, that one of the more important leaks is the popular literature. There, I think, managers find the connection between the scientific possibilities and the satisfaction of a need. If my impression is correct, it means that the importance of the popular literature is rather underestimated at the moment.

Remark

(Holt) I would like to add that we did a similar study in Sweden, where we had one group of engineers and another of R & D people. For the engineering group the results were practically the same as in the United States, but for the R & D group the use of the literature was significantly higher.

Question

I do agree that big firms have a problem here. But I want to stress that meetings of this disciplines. Now we have to assume that these people meet randomly and in a large firm the chances that someone in need of information will meet the right person at the right moment, become pretty small. So a large firm has something to do about this, it has to be organized somehow. Do you agree and do you have some suggestions ?

Answer

I do agree that big firms have a problem here. But I want to stress that meeting of this kind should stay informal, this is very important. Now I do not see any way to organize informality, that is a contradiction in terms. You can create the right conditions for informal meetings between people, but you cannot organize it. Of course you can do many things to stimulate informal contacts. You can transfer people to another town or another country, you can arrange for your people in the field to visit the laboratories, production department and so on, and ask them to tell everyone who wants to listen about their problems. And you can ask a research man to visit a customer. That is quite an experience for both, and if all goes well, they will soon start to educate each other quite wonderfully.

French government policy in favour of innovation

Prof. Dr. R. Saint Paul
Centre d'Etudes sur la Recherche et l'Innovation
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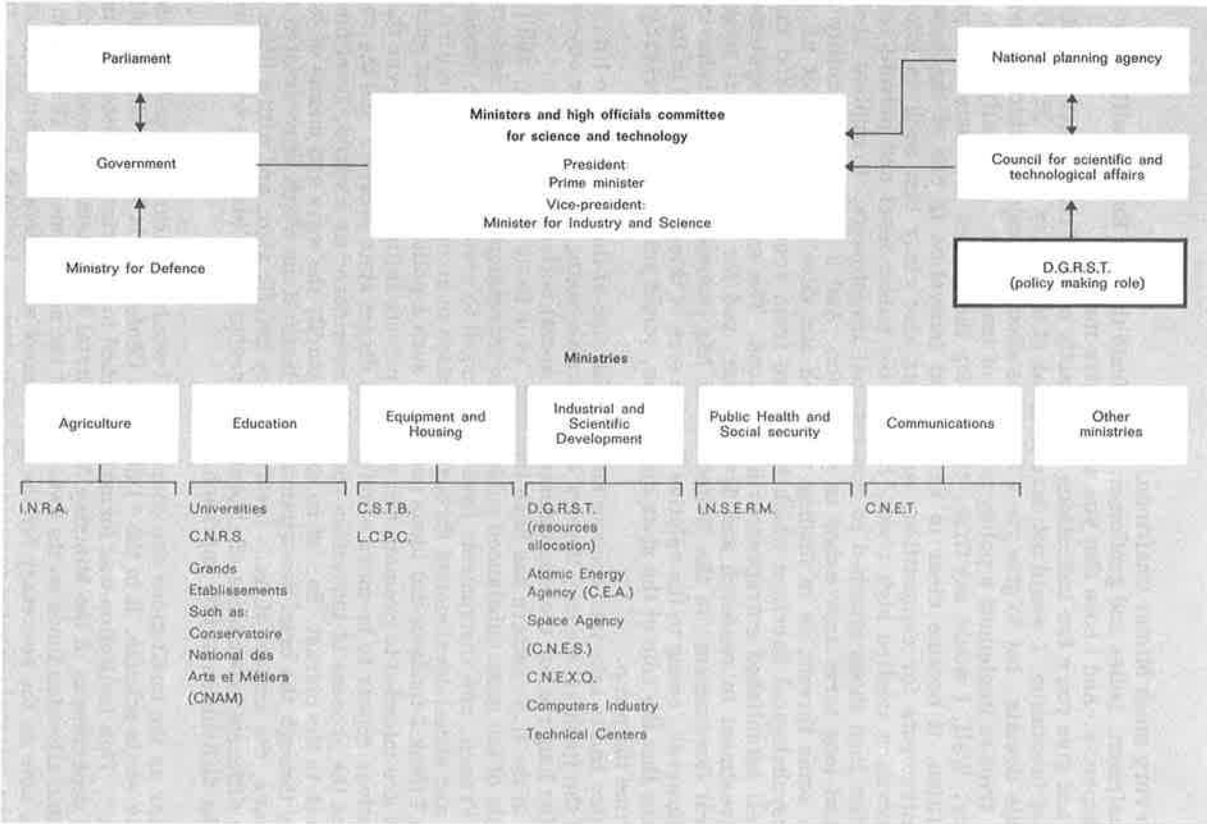
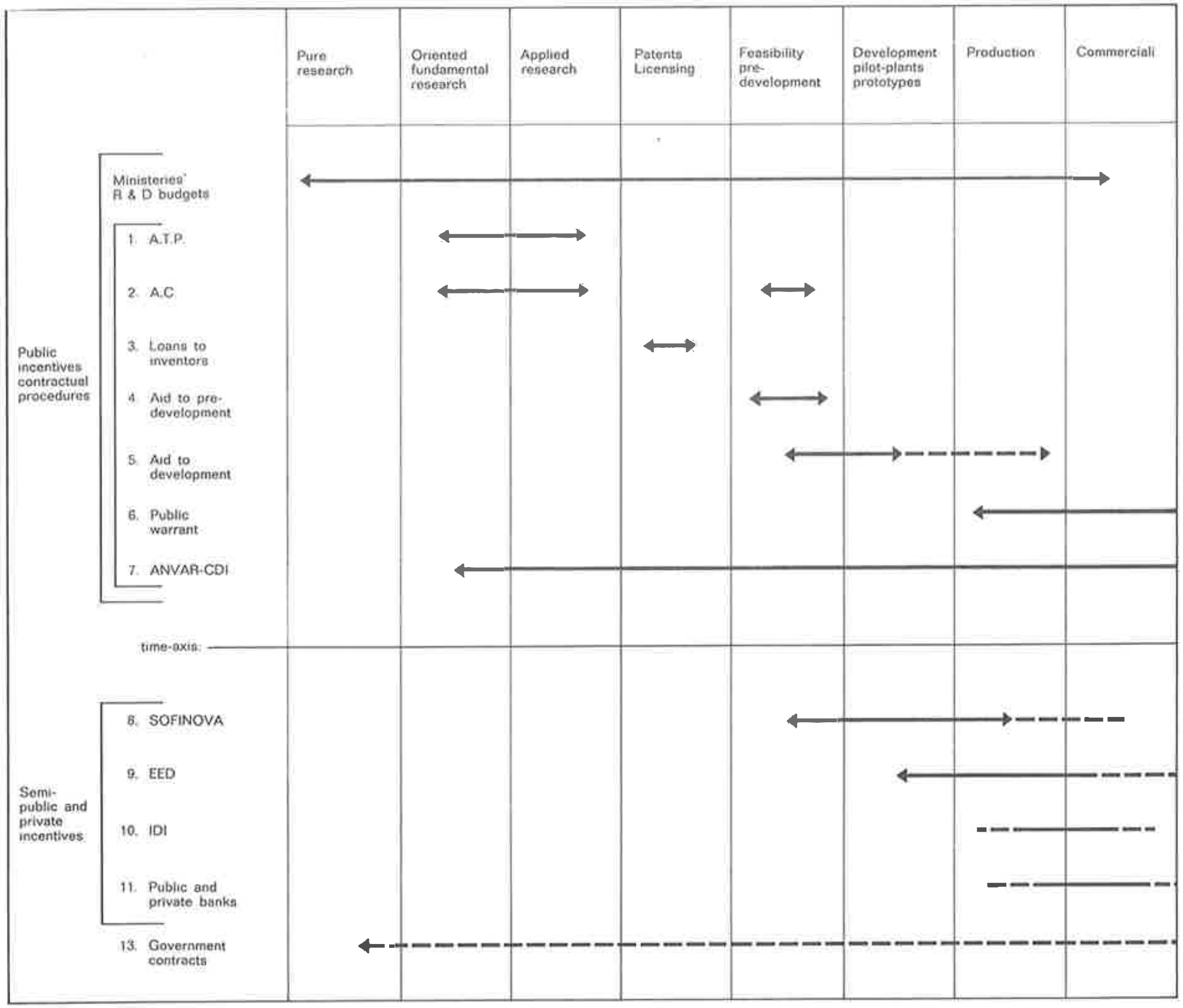
France

Thank you very much Mister Chairman.
Mister Chairman, ladies and gentlemen I am afraid that my English will not be as fluent as Mr. Shapero's. And I hope that you will forgive me.
I will try and give you a few indications, not exactly on the French Government policy in favour of innovation, I would not dare to speak of the policy of the French Government in this domain, but to give you a few hints about the ways in which French government tries to implement a policy in favour of innovation, especially in the private sector. Well, I would say first, that during the sixties and under the pressure of competition, it became clear in France that innovation is one of the most powerful instruments for competition. And it was also clear that such an effort towards innovation implied high risks, both at the public level and private level. Much higher than those attached to conventional investments. It implied also a broader and long term approached to production. And it implied the ability to overcome some thresholds in funding research and development and let us say to destroy psychological barriers which had risen from acquired habits and the comfort of well established entrepreneurial positions. The example of a systematic effort of investment in research and development, and for the main part financed by the Federal Government, in the United States has induced a similar behaviour in France. However, owing to the relative limited size of this country, and of its industry, it is obvious that the role of the state authorities, would yet be more necessary, be it only to prime the pump.
Such a policy had to take into account not only the size of the country, the limited amount of the financial means, the new types of risk-taking, but also new objectives to be set in the long run for the implementation of social collective needs.
However, if the U.S. pattern has been imitated, even to its imperfection, and I think for example of the quite unbalanced public funded investment in different sectors of industry in France, new instruments have been forged to create favourable conditions for economic and social development through innovation in an open and competitive system. And there I think 2 fundamental ideas underline such a policy. First is that such public incentives are intended to promote and support private initiatives, whenever those private initiatives appear to be more efficient than direct state control. And the second idea is that the process of innovation should be considered as a whole, from fundamental research to the market. So, let us examine briefly the ways and means of executing this policy through the brief description of the institutions which were created in the last 10 years, the amount of funds involved, very briefly also, and with a little more length the different procedures of allocation of resources. Finally we will try and comment on the difficulties of this approach.

Well, so far as the institutions are concerned, I would say that an agency stands at the core of the whole scheme. It is the "Délégation Générale à la Recherche Scientifique et Technique". This institution was formally attached to the prime minister and is now one of the departments of the Ministry for Industrial and Scientific Development; thus it receives and allocates funds on its own. But, at the same time, this Délégation à la Recherche acts as the secretary for the government and different committees and counseling of tha national planning organization for instance. And in this capacity, DGRST is commissioned directly by the prime minister to prepare decision on allocation of public funds to research and development and to elaborate a general, short, medium and long range policy in research and development (see chart I).
This institution is closely related with the different technical ministries and the central planning agencies. It makes a survey of the amounts of the investment in research and


Parliament
Government
Ministry for Defence
Ministers and high officials committee for science and technology
President: Prime minister
Vice-president: Minister for Industry and Science
National planning agency
Council for scientific and technological affairs
D.G.R.S.T. (policy making role)
Ministries
Agriculture
Education
Equipment and Housing
Industrial and Scientific Development
Public Health and Social security
Communications
Other ministries
I.N.R.A.
Universities
C.N.R.S.
Grands Etablissements Such as: Conservatoire National des Arts et Métiers (CNAM)
C.S.T.B.
L.C.P.C.
D.G.R.S.T. (resources allocation)
Atomic Energy Agency (C.E.A.)
Space Agency (C.N.E.S.)
C.N.E.X.O.
Computers Industry
Technical Centers
I.N.S.E.R.M.
C.N.E.T.


Pure research
Oriented fundamental research
Applied research
Patents Licensing
Feasibility pre-development
Development pilot-plants prototypes
Production
Commerciali
Ministeries' R & D budgets
1. A.T.P.
2. A.C
3. Loans to inventors
4. Aid to pre-development
5. Aid to development
6. Public warrant
7. ANVAR-CDI
Public incentives contractual procedures
time-axis:
8. SOFINOVA
9. EED
10. IDI
11. Public and private banks
13. Government contracts
Semi-public and private incentives

development which is about at the moment 17 thousand million new francs, aproximately, with a scientific personnel and engineers full time equivalent of about 200.000. But, what is important, is that the financing of this continuous process of research and development is done through the annual allocation of research and development resources to the different ministries and agencies. And through them to public, semi-public and private firms and also ofcourse by selfowners of private firms. But what I would like to underline is that the annual budgets of those different institutions are themselves oriented by the directives of the 5-year plan, and voted by the parliament. The underlying idea here is to spend the available money in the least bad way possible in the light of general objectives. So, a number of different procedures have been created.

Let us consider a time axis where I put pure research at the beginning, then we have a oriented fundamental research, then applied research, then patents and licencing, then feasability and pre-development, then development which is pilot plants, prototypes, and so on, then production and then market commercialization.
To those different stages from pure research to the market, correspond different specific procedures of funding, additional to the normal budgets of the ministries (see chart II).
So, we have first ATP's which cover from oriental research to applied research. Then we have AC's which cover about the same field. Then we have patents and licences, which is here, loans to inventors. Then we have feasability and pre-development which covers about this field, public warrant which is at the bottom and then ANVAR which covers the whole field. This is for the public incentives. Which are those different incentives? Well, let me give a few indications about the different systems.

ATP means "Action Thêmatique Programmêe". What is it? It is a new procedure of allocation of resources, through free institutions, which are the National Centre for Fundamental Research, the Health Research Centre and now the Transportation Research Institute. The purpose of this procedure is to overcome interdisciplinary barriers. It consists in defining objectives and corresponding financial means for basic research in certain domains. The financial means should match all the needs to fulfil the objectives. Then different labs, public and private together, which is new, can submit their proposals, which are combined in a consistent program. The financing of this program is provided for more than one year at a time.
AC means "Action Concertêe". This procedure is under the control either of the DGRST (Dêlêgation à la Recherche et Technique), or of the Department of Defence. There is a clear cut between the civilian activities in Action Concertêe and the military. Here the underlying idea is similar to the one of the Action Thêmatique Programêe, the purpose is to provide a multi annual funding for research teams from both public and private sector, which would submit projects consistent with the priorities defined by the national plan and the national interest program set by the government. The appropriation in this field for the actual sixth plan is more than 1 billion francs and this funding is allowed under four main conditions.
First, the action proposed should be complemented, it should not be a substitute to an existing organism but on the contrary it should rest upon an institution whenever it exists.
Second, it must be a temporary action - not longer than 5 to 6 years - and it is designed to accelerate a process or to verify the interest of a new method. If results prove that the Action Concertêe was well founded, it is then either followed by an existing institution or it generates a new permanent agency of a certain sort. For instance an Action Concertêe on computers led to the creation of a national agency called "Dêlêgation à l'Informatique". An Action Concertêe on space led to the National Space Research Centre. Another Action Concertêe on the use of the oceans led to the National Ocean Research and Exploitation Centre, and so on.
And if the AC fails in this mission, then it is merely surpressed.
Third condition, this Action Concertêe should be a selective action. Only projects within the domains defined to be of national interest, can be accepted for financing.
Fourth condition, the research that follows from an Action Concertêe should in prin-

ciple not be carried out by public laboratories only, but by an association of public and private laboratories, in order to provide for development of the results by industry. At the moment a number of fields are covered in this way: Instrumentation, electronics, automation, macromolecular organic molecules, machine tools, agriculture, food technology, and research on buildings and building materials.

In each case, the final decision is taken by the head of the Délégation Générale à la Recherche Scientifique under the advice of a special committee of experts, which are nominated by the Minister for Industry and Scientific Development.

Then we come to the fourth procedure: Loans, loans to inventors. Well, individual inventors can apply through an organism which name is ANVAR, "Agence Nationale pour la Valorization de la Recherche ", which is a public agency which has power to make loans to inventors to help them to patent their inventions. But I'll come back to this point later, when we will have to say more about ANVAR.
Let us come to the fifth point: Aids to pre-development. This type of aid is under the responsibility of the Ministry for Development of Industry and Science. The purpose here is to foster close relations between professional research institutes and private firms which intend to develop new products and new processes. For many firms, belonging to, lets say, traditional sectors - leather, paper, textile, and so on - the research effort goes through industrial centres for Technological Research, which we call in French "Centres Techniques Professionnels ". These centres exist in a number of sectors and are normally financed by levies paid by the firms in the sector. So that the purpose of this "aid to pre-development " is to help the small and medium sized enterprises to make use of the output of research in their own production apparatus and sometimes to ascertain, whether some result can be of interest in other, neighbouring sectors. So that this "aid to pre-development " will for instance contribute to the development of a proto-type, provided that the Technological Centre can guarantee another source of funding which corresponds to at least one third of the estimated total cost of the project. The observed costs of the projects for this category of proto-types range from 200.000 francs to about 1.000.000; of course, public support tends to reduce the financial risks at this stage. Here the domain for the aid to research and development is not limited, the projects are put in form by the corresponding Technological Centres and the Ministry of Development and Industry and Science, which will cover up to 60% of the total costs.
Now we come to the "Aid to development ". This procedure aims at facilitating the transfer of research results to productions, the last stage of production being excluded. This procedure of "aid to development " is under the control of Délégation Générale à la Recherche Scientifique. So, here is the question of development. This stage is very difficult for the industry; it is necessary to estimate, to test, the real economic value of a specific research and development effort; it also is one of the most expensive. Here again, the contribution of public funds is designed to share with industry the risks inherent to this stage. An aid to development covers, by public funds, 50% of the estimated total costs of development. This amount is included in a contract between a firm and the government. In the event of failure of the project of development, this 50% loan to industry is just turned into a subsidy. In case of success on the contrary the firm will repay the Treasury, its loan, plus a bonus, a bonus which is discussed before signing the contract. The rate of this bonus is generally about 20%. Another compulsary provision in case of success is that repayment must be complete when specific returns of the project are reached. The liquidating period is calculated taking to account the estimated life of the product on the market.

There are three conditions which are set to make a project acceptable under this procedure. First is that the firm should demonstrate the technical and economic interest of the project; second, there should be an unquestionable technical or commercial risk, and third, it should be demonstrated that the financial capabilities of the firm are not sufficient to support the project. When those three conditions are met, then the enterprise can submit the project and there is no limit as to the domain of the different projects which can be submitted. At the moment this procedure covers a very wide range of sectors which are merely chosen by the Ministry according to the different proposals presented by the firms, by committees of representatives from industry and from administration.

There is very wide advertizing in order to encourage precise project proposal from enterprises. Up to now a number of sectors have applied for such an aid: machine tools again, electrical equipment, electronics, chemistry, metalwork, housing, public work, water supplies for instance.

Then we have the "lettre d'agrêment": Public warrant, I think is the nearest English translation. The "lettre d'agrêment" is quite a new procedure. The object of it is to support a firm temporary at the stage of marketing an innovation. A new law, enacted last year, has created a fund which gets its resources from contributions of affiliated firms and from a capital endowment from the government. This procedure allows a firm to warrant the new products which are not yet sold on the market and to obtain credit facilities to finance the stocks. It allows the project to be financed on the same basis as if it were a public project and makes it also possible to get credits from private banks supported by the warranty of the State. Thus, this incentive can help to fund stocks, pre-production, special tooling, the industrual and commercial launching of new or improved materials and products, and finally, new production processes.

Last but not least ANVAR: National Agency for Research Valorization.

Here is with us today the deputy director of ANVAR, Monsieur Rodocanachi, who can answer questions if you like on ANVAR; moreover Mr. Rodocanachi was also for a long time at the Minister's Cabinet in charge of the National Policy for Funding Research and Development.

ANVAR has been created in 1967 and it has a number of purposes. The first one I think is the most important, is to guide private firms, through the long and difficult process of innovation, to help them to transfer the results from one stage to the following in this process; to act as a consultant with firms to make use of the different procedures of support made available to them by the Ministries. This is its first role.

Its second purpose is to try to match supply and demand of inventions. By canvassing the potential market, both trying to find which firm could be interested by an invention submitted to ANVAR, and trying to answer the questions of firms as to the best scientific or research organization that could solve the specific technological difficulties.

This is an answer to what Professor Shapero said a minute ago.

Another role is to participate, if it is appropriate, in the development of projects if their estimated cost is less than 500.000 francs.

But in no case, ANVAR can finance production itself. It can also help inventors in the process of protection of innovation, and then it has a role to foster the idea of innovation through recently created "Centre pour la Diffusion d'Innovation".

An then there is a last means, which I did not mention yet, but which is very important; it is a way of financing research and development in industry through public contracts which has proved very successful. Public contracts that express the public demand for products and processes from state Ministries, Agencies are a very important incentive towards innovation. These public contracts amount annually at the moment to about 60 billion francs, which represent about 8% of the gross domestic output. Each of the, what we call "big buyers", can include in each public contract to private firms, specific appropriations for research and development; the total amount is about the equivalent of all the credits which we have for the aid to development. Moreover, in those public contracts there can be additional clauses, providing sums for free research and other costs. The idea underlying this procedure is that the responsibility of innovation should be on contracting firm which has to face intense competition and that such a flexible procedure is adequate to the specific needs of industrial research and development. Moreover, and although they are not strictly speaking direct incentives to innovation, it is important to note the development in the private sector, of such organisms as: E.E.D. (European Economic Development) and SOFINOVA (Sociêté pour le Financement de l'Innovation), the role of which is to finance the output of R & D on a venture-capital basis.

Then I should mention a number of indirect incentives, but time is running very short.

I would simply indicate that those indirect incentives are tax regulations, which is a rather complex domain. We have a number of tax regulations to stimulate actions in common, or to facilitate the development of Technological Centres and so on. Also there are a number of systematic actions in training engineers, administrators and scientists in the different methods of allocation of resources, of management of research and development, of technological assessment and of technological forecasting. Another kinf of indirect incentive, just to try and change the way of looking at things of people in the industry, is for instance the recent creation of a national foundation for innovation which has a private status and which is launching next June in Paris a large exhibition of new products, "INOVA".

So to sum up, it can be said, I think, that the instrument of a policy in favour of innovation exists at the moment in France.
But the important fact which I have not yet mentioned, is that this whole policy is underlined by a will to enforce competition; the idea is that competition is the best aid or inducer to innovation in the industry. But this competition leads to very high risks and the State has a role to help the industry to take those risks.
At the moment the situation in France has considerably improved, so far as innovation is concerned. Industry seems to be more and more interested in innovation, the difficult point is now to define objectives for innovation in the civilian part of industry.
To define objectives for social development through innovation is a very much more delicate affair, then was the problem of research and development in the sixties.

DISCUSSION

Question

(Chairman) Perhaps I may start with a small question. In the beginning of your lecture, you said you would not talk about policy, but more about measures. But I think you did talk about policy too, and I heard you mentioning a five-year plan which directs the first stages of subsidizing. Could you say something about that five-year plan? Is there a definite science policy in it, and to what extent does it have effect on the various stages you mentioned?

Answer

Mr. Chairman, a good answer to this question would fill a book. There is, however, a definite, broad science policy in the five-year plan. In the first place it should be recognized that this may have a negative effect: If a proposal, made during the time-length of the plan, does not fit in with the general view expressed in the plan, there are higher chances that it will not be accepted at all.
Secondly, there is the procedure of the 'enveloppe-recherche', which is another fund, the amount of which is discussed between the Minister of Finance and the "Délégué Général à la Recherche Scientifique et Technique" under the control of the Prime Minister. The sums involved in the 'enveloppe-recherche' are allocated on a one year basis to the different Ministries, in addition to their own R & D budgets. In this way, D.G.R.S.T. can, at the margin, modify progressively but efficiently the orientation of the different sectors of applied research, according to the general objectives set in these fields by the Plan.

Question

(Chairman) In your lecture you mentioned that the plan involved objectives for fundamental science, but to me it seems very difficult to make a plan on fundamental science.

Answer

It certainly is an understatement to say that it is very difficult to make a plan on fundamental science. On the one hand, however, fundamental research implies money, and money has to be allocated; in this way pure science comes into planning process against other possible expenditures.
On the other hand, there are various Commissions and Committees within and outside the planning exercise, where some kind of consensus progressively emerges from lengthy discussions. The consensus is made up, more or less coherently, of objectives and means, and these can be the definition of a 'plan' as soon as it is proposed by the Government and accepted by Parliament.

Question

In the last part of your lecture you mentioned public contracts and you said that there is a provision for funding research and development of those who submit the contract. Is that provision open to foreign bidders?

Answer

Under certain conditions, why not? After all, didn't we create a Common Market?

Question

You mentioned that one of the instruments for an innovation policy in France is aid to research and development. In other European countries similar tools are utilized, and if I am well informed, I think that in the Netherlands the system is almost exactly the same as in France. My question is about the rate of return on this instrument as far as the Government is concerned. Does it pay for the Government? If not, how much do they lose?

Answer

I think that your question is two-fold: Does it pay for the Government to have this policy and does industry pay back the sums invested? I'll try to answer both. It is, I think, indispensable that the Government should have a policy for the support of research and development, all industrialized countries have procedures for it. It has been recognized that investment in R & D is a high-risk investment, which under certain circumstances should be supported by public money.
As to the second part of your question, pay-back depends on the success of the innovation. As I said in my lecture, if it is a failure, aid is turned into a subsidy, but if it is a success the whole sum will be paid back plus a bonus. The conditions for this are in the contract concluded between the Government and the industry. But at this moment it is difficult to give you some figures, as the process of development is too long and the procedure still is too young. Nevertheless, we have already a few instances of successful innovations and in these cases the industries have started to pay back the original investment. Maybe Mr. Rodocanachi has some comments on this part of your question.

(Rodocanachi, Agence Nationale pour la Valorization de la Recherche) The procedure of aid to development has not been set up to ensure the pay back of the investments in all cases, as it is well-nigh impossible to predict the success of an innovation. We think that we will have been successful if some new inventions are put on the market. We have used the procedure since 1965 and we have indications that about 40% of the projects have been a success, which does not mean that the industries involved all have already paid back the investments. But we have to wait, maybe, another three years before we know whether our choice of projects was really good.

Question

You have shown us a very complex system of aid to innovation processes, and in addition France is investing large sums of money in pure research. All this must create a tremendous amount of technological know-how. In Germany we have rather serious difficulties with the transfer of that know-how to industry, and if it is to be used for innovations, it has to be transferred to industry. So my question is: What is the French Government doing to foster the transfer of this know-how? I do not mean still other financial incentives, but things like the promotion of the mobility of research workers, promotion of good communication and so on.

Answer

Well, it is one of the tasks of ANVAR to try and find in the research centres the people and the ideas which could be transferred to industry. It is also the task of ANVAR to try and find the problems in industry that cannot be solved there, but that probably could be solved by some research centre. The idea is to have a two-way channel of communication through ANVAR and this was perhaps the main reason why the Agency was founded in 1967. At the start there were many difficulties, but it seems to work rather smoothly now. The procedure is still rather young and there are various psychological problems, directly linked with the mobility of research people, the attitudes towards secrecy in industry etcetera.

Question

Could you give an indication of the various amounts of money distributed by the various agencies, ATP, AC, Loans to inventors and so on?

Answer

I'll try to give you some figures. In 1972 the sum for the 'Actions Thématiques Programmées' amounted to about 32 million francs, which is expected to rise to more than 40 million francs in 1973.
In the 6th Plan, which will end in 1976, the appropriation for the 'Actions Concertées' is over one billion francs; however, mainly due to scarcities in available highly qualified personnel, it is not expected that the total expenditure will exceed F. 700 million.
As to the aids to pre-development, the 6th Plan earmarked F. 100 million, of which F. 9 million were allocated in 1972.
In the same year about F. 300 million were spent in Aids to Development, out of the 2000 million foreseen in the 6th Plan.
These are but rough figures; for detailed information I would advise you to apply either to the Ministry for Industrial and Scientific Development, 101 rue de Grenelle, 75007 PARIS; or to ANVAR, 13 rue Madeleine Michelis, 92200 NEUILLY SUR SEINE, FRANCE.

Question

Can you give us an idea of the time that elapses between the proposal and the appropriation of the money?

Answer

That depends very heavily on the procedure and on the project. With 'Aide au Développement' the time elapse will range from three months to less than one year. For 'Action Concertée' the time elapse will be longer, because there you have a large commission of experts chosen by the Ministry. And I did mention that the director of the 'Délégation Générale' can on his own allocate funds almost without administrative delay if he thinks that the problem is very urgent.

The role of the market and the market research
The SAPPHO Project

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Ralph Waldo Emerson is supposed to have said: "If a man write a better book, preach a better sermon or make a better mousetrap than his neighbour, though he built his house in the woods, the world will make a beaten path to his door." Does anyone believe that. The Oxford Dictionary of Quotations says that there is no proof that Emerson actually said it, so we don't have to blame him for an odd piece of thinking. It is a rather strange statement to make, because unless the book is published and the sermon addressed to an audience and the mousetrap used to catch a mouse, the world won't even know where it is all happening. So how will they make a beaten path to the inventor's door? Do inventors themselves think like that? On the whole they don't.

In working on the SAPPHO Project* and reading the copious literature that lies behind it, it becomes clear that inventors are very tenacious people and when they have got an idea they know that the only way to get satisfaction from it is to put it in a marketable state, to reduce it to practice as the engineers say, to sell it and to make money out of it. In other words the inventor wants to innovate, using the word innovation here to mean the whole of the innovation sequence from the idea for the invention right to the marketing process. If we don't look at the innovation sequence as a whole, words like success and failure change their meaning. In the SAPPHO Project we never meant by failure that the invention had been shelved at the research or development stage, we meant that it had reached the marketing stage and failed then. It had failed to gain the market share intended for it by the company, or had failed to be profitable, or both.
In the SAPPHO Project we took pairs of successes and failures and compared them in great detail. We started with a group of 30 pairs, which we reduced to 29 for a rather painful reason, one of our successes was Corfam, and while in 1968 you could believe it would be a big success, in 1971 even Dupont decided it wasn't. So we finished with 29. We have now collected additional data and by rearranging the pairs, we have 43 to analyse and the results have come out very much the same.
But what is the purpose of such a project or any of the projects in studying innovation? One purpose, apart from the sheer academic pleasure of the research, would be to try to narrow the area of uncertainty, to reduce the risk, and thus perhaps do a service to industry. Having talked to a great many firms about innovation in two sectors, the chemical industry and scientific instrument manufacture, I came to the conclusion that firms are over-optimistic and they do still have this better-mousetrap attitude, and the market penalises them for it. Many of the firms we looked at among the less successful group had been heavily penalised in a commercial and a financial sense. Perhaps some of them deserved it not because they were over-optimistic, but because they did not do their preparation for the market properly. But let me add a warning that the marketing factors, while they are very important, are no more important than others. The firm cannot afford to ignore the other factors. You can't leave the research and development to be done in a fairly haphazard way and hope that good marketing will take over and sell the product.
In the SAPPHO Project we identified about 200 factors which were reduced eventually to 10 groups of index variables or groups of factors, and one of them was a very important one: the marketing group. The way we did it, very briefly, was to take the suc-

* SAPPHO stands for: Scientific Activity Predictor from Patterns with Heuristic Origins

cessful and less successful cases as far back as we could in the innovation sequence, not beyond the generation of the idea, not back like the Traces Project did at Illinois to the fundamental research done perhaps 50 or 60 years before, but just to the discovery or rediscovery of the basic idea. Many of the innovators used established technology to develop a new design of instrument or a new chemical process that they hoped would revolutionize the marketing situation. What we were looking for were the key differences between what a successful innovation sequence showed as characteristic and what a less successful sequence showed.

The five main groups of differences were, first that a successful innovator looks at user needs with much more care than the less successful. It is not merely that he designs something which he thinks will be attractive or useful, he thinks about how it will be used and in what situation it will be used.

Secondly the marketing side, which is not precisely that of user needs, but publicity, preparatory market research, sales promotion, a whole battery of marketing skills.

Thirdly, the successful innovator does good development work. In the chemical industry we found that a majority of the successes were first on the market and in the instrument industry it was the opposite way round. At the same time there was a clear indication that the development work was more thoroughly done by the successes, as you would expect. It seems fairly logical and even obvious too.

Fourthly, the outside communication of the firm with the scientific and technological community was good in most cases, but in the success cases it was particularly good in the area of the innovation itself.

These were controllable factors, things the firm could decide to do and to carry out, but the fifth factor was not so controllable; it concerned people. Creativity generation and communication are human activity areas which are difficult to understand and to control and guide. Our fifth group concerned the characteristics of the business innovator, the man who is responsible in the company for seeing the innovation right through to the market from the inception of the idea or the licencing. He showed different characteristics in chemical firms than he did in the instrument firms. For instance, in the instrument firms he'd have much more varied experiences, a more mobile career. Altogether he'd be generally rather younger. In the chemical industry he'd been in the firm longer, he had a more stable background and less varied experience, although between the pairs of chemical firms the successful business innovators on the whole showed more variety of experience, but far less than in the instrument industry.

The results and the method have been published in a short booklet, "Success and Failure in Industrial Innovation", obtainable from Sussex University*.

In the results there are seven factors that have marketing aspects: one is user needs; then there are fewer after-sales problems (this comes from better understanding of user needs plus good development work); greater sales effort on the part of the firm; the education of users (an interesting one, because often a high technology product like a very elaborate scientific analytical instrument does require that the people who buy it to use for analysis, should understand its scope and how to use it for the best); less adaptation by users means that the innovation meets their operational requirements; then came the question of publicity (making known what you are doing, not being too modest or too secretive); and lastly a touch of ruthlessness on the part of the innovating firm, cutting out products or processes to make way for the innovation, a difficult decision because of the risk element, and firms don't like to take apparently unnecessary risks.

What worried us about these groups of factors was, that while they did give us some hints about the difference between success and failure in innovation, they did not in their broad form tell uss very much about what firms should be doing to reduce their failure rate. The following table was devised by the Society of New York Sales Executives and it shows the contrasting attitudes of companies to the consumer, see table. On the right is the policy of the production orientated firm, and that of the marketing

* Success and Failure in Industrial Innovation, Science Policy Research Unit, (£ 1).

MODEL OF THE MARKETING CONCEPT

MARKETING-ORIENTATION	ATTITUDES	PRODUCTION-ORIENTATION
Consumer forces dominate; emphasis on long-range planning	OBJECTIVES	Internal forces dominate; emphasis on efficiency and technology in the short run
Decision making starts with the consideration of the consumer	PLACE OF THE CONSUMER	Decisions are imposed on the consumer
Company makes what it can sell	PRODUCT MIX	Company sells what it can make
Used to determine customer needs and test how well product satisfies these needs	ROLE OF MKTG. RESEARCH	Used to determine consumer reaction, if used at all
Create new markets as well as serve present markets	MARKETING STRATEGY	Satisfy existing markets
Focus on market opportunities	INNOVATION	Focus on technology
Sometimes lead, sometimes follow; offensive posture	COMPETITION	Always follow, react; defensive posture
An objective	PROFIT	A residual, what's left over after all costs are paid
Focus on marketing problems	OTHER CORPORATE FUNCTIONS	Focus on manufacturing and finance problems

CONSUMER

MANUFACTURING

SOURCE: "Adoption of the Marketing Concept–Fact or Fiction?" by the Sales Executives Club of New York, Inc. (1967).

TABLE

oriented firm on the left. The innovative marketing oriented firm focusses on opportunities, in other words, looks for needs and tries to fulfil them. The production oriented firm is more technology minded and is constantly pushing forward the frontiers of knowledge. There is nothing wrong with that, but there is always the danger of perfecting new products and processes which may not have a market opportunity confronting them.

We thought, and so did our sponsors, the Science Research Council, that we ought to go into more detail and find out what it was that led firms into the launching of unpromising projects. We went back to study files. We kept a file on each pair with all the interview notes and so on, so one could go back through the history of the innovation, looking at it from a different point of view. Originally all we had done was to pull out simple yes-no answers for coding purposes. For example, was the less successful firm larger or smaller than the more successful? Where a firm was larger or its R & D allocation was larger, or some comparison like that, it got a 1 and its opposite a minus 1. That was a statistical and rather abstract excercise.

The files yielded 34 usable failure cases, that is to say the other nine - I mentioned 43 - either were already duplicated or the files were not really up to yielding the sort of information we wanted. Looking at the marketing side, out of 34 failure cases in the group, we found that 4 had made no enquiries at all about potential users, they had not asked them what they precisely wanted; 6 had made too few enquiries, 2 had ignored the results of their enquiries, 2 misinterpreted the answers they received, and 6 were already committed to designs that they had decided upon before they made the enquiries, and there were 3 others who failed to understand the on-the-spot use to which the instrument was going to be put. All these were avoidable errors, and the successful innovators avoided them by taking what might be thought to be obvious steps to ensure what we came to call 'close-coupling' with potential customers. For example, one instrument firm demonstrated working models of its new design of instrument to a select group of potential users and kept in touch with them throughout the development and production stages, consulting them about prices when their cost estimates turned out to have been too low, a not uncommon occurence in innovation. Another firm, aware that while its new instrument worked on known physical principles, they had been applied successfully by only a few others, gathered up all the available publications that these experimenters had put into print, abstracted it, added a bibliography and mailed it to a large number of potential customers, inviting them in return to tell about their experiments with the instrument which could be borrowed, or to come to the firm with a sample they wanted analysed, which would be done for them by a resident analytical chemist. This firm had recruited chemists specially, something instrument firms were not doing at that time. The firm not only took 75% of the world market, and still holds something like 60% in spite of 14 competitors, but that newsletter it send out has become a very famous quarterly in the world of atomic absorbtion spectrometry.

A third example is that of a firm, while willing to design a device to the stated needs of a client, pointed out the limitations of accuracy that would occur in practice as a result of human error, and was able to agree upon a working compromise. In this pair, the unsuccessful firms set out to meet the ambitious demands of a customer. These were two firms innovating optical character recognition devices, and the one who aimed high lost the game, while the one that was more practical and aimed lower within its own capabilities and the limitations it knew it's customer would impose upon the system, succeeded.

The understanding therefore of user needs requires that the innovating firm should make few assumptions and preferably none about what potential customers want, but check at every stage the reality and practicality of harmonizing potential users' demand with his own capability. Both are capable of change; if a firm's capability doesn't appear to correspond to the customer's needs, then something must be done about it. Similarly, to enjoy good standing with customers, you must say to them: "You are asking too much."

The probability of a wider market rests on initial successes. In technological innovation quite a lot depends upon the reputation that a firm enjoys and if it has perhaps one or two successes to its name, it will become known throughout its sector of industry

and will be looked upon as someone to approach in the future and not someone to ignore.
The second group of factors which I mentioned examine in detail the marketing activities of the firm, and it may seem artificial to draw distinction between user needs and the marketing apparatus of the firm, such things as market planning and marketing research and so on. But none of these, not even industrial marketing research, can always provide that understanding of user needs which seems to be essential to successful innovation.

Within the 34 failure cases which we scrutinized, 11 of them had done no market research or had neglected to apply the findings completely; 7 had put too little effort into marketing in general, including publicity, 5 had paid too little attention to user education and 7 had suffered from unforeseen changes in the market which they might have been able to predict had they had better intelligence service. Those seven firms were overtaken by events, and this can always happen.

When the cases are looked at individually to find some explanation for such apparently careless behaviour, and not perhaps the last seven, but all the preceding ones, neglect of market research is frequently associated with the preconception of a need. In other words, the firm has assumed the need. It could be right, but it is a dangerous assumption to make. One of the firms innovating electronic document readers undertook a kind of market forecast called sector analysis, seeking what sectors in the future would be promising to be in. Document scanning was one that they thought would be good, concluding that with the growth of computer installations some form of quick input would pay off. The reader would leap the punchcard stage and go straight to punching tape into the computer. It failed to recognize that there might be intermediate technology, in other words mark sensing which is much simpler, mark or no mark, not trying to read 26 letters and 10 numbers in three or four different typefaces, which was their ambition. They thought it was a big technological challenge, they were right, and they did not quite make it. They made a good machine but the human error of the input involved was not taken into account thouroughly and they never sold more than three of those devices.

Similarly, a firm collaborated in the design and production of a non-chemical milk analyser with an inventor in a government laboratory in Britain, assuming that it would find ready acceptance in the diary industry. Milk analysis by chemical means is costly and slow, labour intensive, and with an acid effluent. A non-chemical method is preferable. Because it was working with a diary research institute, the firm neglected to verify this assumption and was later disappointed to have its instrument rejected by the most influental customer in the dairy industry, the Milk Marketing Board of England and Wales, on the grounds that it was too versatile and too elaborate and too expensive. Its successful rival, which came from Denmark from a very small firm, took the trouble to make preliminary inquiries in their own dairy industry. In fact the firm quintupled in size as a result of this innovation.

A third firm made the mistake of assuming that public health regulations which concerned the presence of undesirable substances in bottles of liquid for human consumption, would compel the firms in the industry to use scanners to check for foreign bodies in the bottles. They did not recognize the fact that the instrument they were marketing was too expensive and that the chances of a firm being prosecuted for breach of those regulations were very small indeed, two or three times a year at the most and a fine of no more than £ 50, so the write-off period for the instrument would have been far too long. The success firm in that pair succeeded because they had a prior knowledge of the industry, they made complete bottling lines and they sold their scanner as an ancillary.

Where the marketing effort had been small with little or no publicity, there were two common characteristics. With new instruments some firms took the better-mousetrap attitude, associated with a rather cautious approach to the launching of a new device, a reluctance to spend heavily on advertising and a wait-and-see philosophy. One firm with an exclusive licence to make a new instrument was worried about an existing instrument which was a moneyspinner. They thought if they put the new instrument on the market, it would hurt the sales of the current one and also that the investment in the new instrument was too high. So they had a double reluctance. In the end what they did was to make an adaptor kit for use with the old instrument. Unfortunately it did not function to the degree required by customers, but this only became apparent after sales, always a damaging situation. The assumptions they made seem rather contradictory, but they determined the firm's unsuccessful policy. They only sold one apparatus in five years to a very large firm which bought the one instrument, worked on it and reported on it to the manufacturing firm, which felt so unenthousiastic about it that they actually ignored this piece of free development work.

Within the battery of marketing techniques that firms can apply, is this question of close coupling with users the one that is most neglected by innovators, perhaps because it is not attractive to some companies who may feel that they are going to be overwhelmed with advice. That was perhaps the feeling of the instrument firm when they ignored their customer's well intentioned criticisms and suggestions.

As a final example, a company marketing an instrument of rather complex nature, based on a fairly newly discovered physical principle, failed to provide users with an adequate instruction manual. It did not even contain a full set of circuit diagrams, and the instrument was designed in such a way that the chemists who bought it found that they spent half their time getting it to work when they would have liked to spend all their time using it and getting the results they wanted for their experiments.

There is a perilous tendency in instrument design for manufacturers because they are experts, to assume that the operators of their instruments in the customer company will be just as expert, not a wise assumption to make. All these marketing factors which distinguish between successful and less successful innovations in the group of 34 cases can be brought under management control except for the uncertainty of the market, sudden sharp cuts in prices or the sudden appearance of a cheaper, better process or of an instrument that is cheaper but just as good.

Those that are not in business find it surprising that companies actually do make mistakes of this kind, but that they did, we do know. Whether they will be made as much in the future will depend on another kind of innovation, diffusion, the diffusion of this kind of knowledge, and we intend to do our best, with the agreement of these firms, to publish as much as we are able of what they have told us. No doubt the sting has gone out of the commercial wounds over the years, because most of the cases refer to the 1960's and some even go back into the 50's. So it is to be hoped that one day we shall be able to produce a really useful document, which by that time, of course, may itself be obsolete. With innovations, this is bound to happen.

DISCUSSION

Question

Have you been able to find out whether these firms made themselves post-mortem analyses on the various mistakes they made or on other failures they had?

Answer

That is a very interesting question. At the moment post-mortem analyses do not seem to be carried out a great deal. I am working now with two divisions of a very large industry and they are very interested in post-mortem analyses of innovations. We have got one that is actually alive and well, but we think it might turn a little sick in the near future, so we are looking at it from the SAPPHO point of view, to see if we can discover what the symptoms this illness are.

But on the whole the answer to your question is no. Firms do not tend to do this kind of analysis, they tend to say: "Well, it went wrong because..." and then they will give you a reason. Let me give you an example. In the instrument firm that was making the optical character recognition device I mentioned, the chairman said: "We made a serious mistake over this, we were thinking in terms of years, we thought that in a few years there would be a demand for this device. But we should have been thinking in decades." He was right in a way, their whole time horizon was too short and there was not the demand. But at the same time there were other things they could have done which they did not do, and when we talked to the chairman and his colleagues they all agreed with us. They had thought of them and decided against them, and one was this intermediate technology thing. If they would have made a simple mark-sensor, they would have had cash-flow from selling it to subsidize the innovation, they could have taken longer over it, perfected it and maybe eventually made money out of it.

But I think that the investigations we have conducted and are still conducting, have benefited the firms quite a lot. In some parts of British industry there is quite a lot of self-questioning going on. They don't ask merely: Why did we fail with an innovation?, but also: What are we going to do about innovation from the point of view of our own capability and the market opportunities? In other words we may be acting as catalysts but, I think, only in a small way.

Question

Did you meet cases where in one firm where you had a failure and a success? If so, could you find out the reason for it?

Answer

No, we did not have a pair of success and failure within the same firm. We were offered one, but we did not think it was quite right.

When firms try the same innovation twice, they usually try them in parallel, like Dupont did with Corfam. You have two groups working, competing, and eventually you decide which group has got nearest to the technical answer and the marketing opportunities and then you give them the responsibility to go on with it.

I thought you might have meant: Did we find several failures in one firm and looked at them? We did find that and we found several successes in some firms too, I am happy to say. And personally, I would have liked to look at the history of innovation in one firm, taking successes and failures and seeing what the factors were. But certainly we did not do a pair within one company.

Financing for Innovation

Dr. J.W. Spruit
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Originally, the paper of Dr. Spruit should have been delivered before the paper of Dr. Robertson, as announced in the programme. At the Conference, however, it was decided to have together all papers pertaining to the managerial aspects of innovation, and accordingly the paper of Dr. Robertson was presented before that of Dr. Spruit.

The Editor.

I am most grateful to you Mister Chairman for the opportunity you gave me yesterday to change places in the programme with Dr. Robertson and I am grateful to Dr. Robertson for his willingness to allow me to do so.
One of the main reasons why I was rather happy about this change is that as Dr. Robertson already mentioned, the money-man might well be in a better position to express his views after the market analyses took place.
What we have been talking about to a great extent is how to get a new product from the drawing board, through the pilot plan stage, in production and succesffully on the market. And in this process particularly in the last stages, I feel that far more team-work is required. Team-work where the technical aspects, the marketing aspects and the financial potential of the product are given full consideration.
In such a team an industry-orientated banker can play to some extent a co-ordinating role. We see this to a great degree in the United States, where the large American Banks have all developed Industry Departments which have an unusual understanding of the particular branches of industry these banks are interested in. It is also quite amazing to see for an European Banker the depth of their understanding and the contribution which they can make not only to American projects and to American innovations, but just as much to new European introductions. Vital in my opinion for this kind of set-up in Europe, would be a far more industry orientated banking community and a more intensive dialogue between the banks and industry. If such a change in the climate could be brought about, we could undoubtly not only open up the vaults of the banks and thus create a bigger flow of funds, but the variety of funds becoming available would certainly increase too.
If I may draw from my experience in the London money market and the London financial community, we find there more of a specialization between the stock-brokers, the investment bankers, the merchant bankers and the joint stock-bankers. One also notice far more openess and a greater willingness to assist innovation.
If I draw from my own experience in Hambros Bank, which I left quite recently, we had there in the investment banking department a special unit called the "Department of Industrial Services", which was manned by a team of about 8 to 10 people, who had as their initial training ordinary investment analysis, but who had grown out of this more security orientated training into semi-industrial managers.
This was brought about by close collaboration with a second team of industrial consultants, headed by Ian Morrow, a well known city accountant. The industrial consultants of this team had been, each of them, originally managers of their own firms or had been active in marketing in large organizations. They were given a small guaranteed income by our bank and were brought in when we got spin-offs of large industrial groups.

If I may give you an example I would refer to the Plessey Group in the U.K. In this group quite often new interesting products were developed, taken to the pilot plant stage but at that final moment before the product would be brought on the market, the top ma-

nagement, on various occasions, shided away from the responsibility of the very substantial finance required.
As a result I could point to a number of cases in the U.K. today, were 2 or 3 members of the teams of the Plessey organization, having developed a good project, which was finally turned down by their top board, went to the city community, got support and financial backing for their venture.
Engineers were normally the key members of the team, but in a couple of cases there was a marketing expert among them as well. At the same time in nearly all these cases there was clearly a lack of overall managerial planning and lack of ability to push the project a stage further. It were these kind of functions which were then performed by the industrial consultants which I just mentioned.
Being put in as a part-time or full-time directors, in most cases they succeeded after a year or two to build up a normal management team and gradually we were able to withdraw or reduce the role of the directors put-up by the bank.
As a rule no more than 40 - 45% of the funds were made available in the form of equity or long term loans. At the same time we assisted the originators of the project and the people whom we put in from our own organization, by providing them with loan finance so that they could take out some equity themselves to increase their own direct motivation. There has been of course a chequered record with this kind of approach.
Dr. Robertson has mentioned yesterday various cases which resulted in failures and he mentioned the reasons for such failings. In most cases these failures could be tracked back as Dr. Robertson's analysis showed, to the fact that the marketing had not been sufficiently prepared.
A very interesting project which I like to mention in this context, is the development of a new malting process by a couple of brewing experts in a Suffolk brewery. This malting process had some substantional adventages: it made use of a type of grain which could be grown in Scotland and that otherwise would have no outlet; it provided for a continuous process instead of a batch process and it had a far shorter cycle than the traditional methods. This new process could have meant a very substantional saving to the brewing group in which works it was developed, but again the management for undoubtly solid reasons of their own rejected the project and the employees involved did not get a chance to introduce this new idea.
Hambros Bank was approached and we put it in a slightly different context, viz in the context of the Whiskey industry. Ultimately we put in a marketing manager and two directors to concentrate on the agricultural side, which meant the purchasing of the grains and to develop an overall budget control. Within two years this project became a highly profitable development which in the third year was introduced on the London Stock Exchange. It is this element of the London Stock Exchange and the approach of the English financial circles which explains, in part at least this, the possibilities which sometimes one envies the U.K. industry for.
In the U.K. it is possible with in only one or two years, provided of course that the project is an economic one and that the product has a certain appeal to the market, to arrange, if not for a stockmarket quotation at least for a private placement with the institutional investors. In this way the funds available to the merchant banking community and the investment banking community tend due to these efforts to turn-over with a certain speed and as a result with the same amount of funds earmarked for this activity in the banking community a substantional bigger volume of business can be handled over a longer period of time.
Similar activities are of course undertaken by other members of the merchant banking community. We all know about the NRDC, the TDC and here on the continent we see simular activities from the European Enterprises Development Groups in Paris and Luxemburg.
On the whole I would say that an increased inter-play between the financial community and industry should provide for better flow of funds and that with more understanding it should be possible for the banking community to act as a catalyst in taken projects from the drawing board to the end-market.
Mister Chairman, you asked me yesterday to be rather brief in view of the time to be made available for the case-studies and I would therefor like to leave my observations at this for the moment. Thank you very much.

DISCUSSION

Question

During your lecture, I thought that you had in mind the larger projects, that have the research stage behind them and may even have been developed on a laboratory scale. Am I correct in that?

Answer

I was not necessarily thinking of large projects only, in effect quite a couple of projects in the electro-technical industry were rather small.

Question

(Shapero) In the American experience only one in twenty requests is interesting enough for further investigation. So I would like to ask: How many requests do you get every year, roughly, and what is your percentage of follow-up.

Answer

That is an important question, as it touches the selection process. I can only give you figures about the number of proposals that reached the department, as in most cases the director of the bank is first approached and he will turn down projects that are obviously unsuitable. Roughly, about 50 projects will reach the department every year, and of those about 35 will fall off after a preliminary investigation. The remainder will be developed further and the avarage gestation period is two to three years. Although for this catagory the selection procedure is fairly severe, we still have a failure rate of 15 to 20 %, which is rather normal. About 40 % of the projects becomes a moderate success and the remaining 40 % a substantial success, enabling the bank to approach institutional investors or the stock market.

Question

(Freeman) Merchant banks play an important role in the financing for innovation and so do some government agencies like NRDC. Yet one still hears complaints about the difficulty in getting sufficient finance to assist innovators. Would you take these complaints seriously or would you say that, for some time now, lack of finance has not been a major constraint for innovators in the U.K. ?

Answer

I would be very much inclined to react in the latter way. I don't think that in the United Kingdom, or on the continent, lack of finance has really been a major constraint for innovation. A far bigger problem is either, to find the most suitable financial channel, or from the side of the innovator, a rather poor presentation which did not add to the credibility. But with proper presentation, I think it would be rare for a good project not to find its financial backing. This may be slightly easier in the U.K. than on the continent, but that is another point.

Question

I have never known a merchant bank to be a philantropic institution. Now you said that after the main board of a firm has turned down a suggestion, then the people who put up the suggestion regularly approach a merchant bank. On what basis do they come to you? Do they come as individuals through the back door, seeking alternative finance and do you accept that with an eye on the possible profit? Or do they come with the blessing of the main board who just wish to opt out and put the risk in another camp?

Answer

In a bank we certainly cannot have people coming in by the back door. The best way to answer your question is by reverting to my example from the malt industry. It were not necessary the most rational motivations which made the board of that particular brewing company to turn down this idea, on which they had spent quite a bit of money to take it to the pilot plant stage. They were not willing, to a large extent for traditional reasons, to see it through. Then the people who had developed the process, resigned their positions in the company and started looking around for sponsors in the city, and in this way they came to us.
And I certainly hope that I have not given the impression that merchant banks are philantropic institutions. We are not, we are certainly extremely keen on our profits, because in this field the risks are above average.

Question

I would like to ask two questions. Is the gestation period of three years you mentioned typical, or can it be much longer or shorter? What happens to these companies after they have been introduced on the stock market, does it happen that a large industry buys them up or do they really become small companies which can exist on their own?

Answer

I am grateful for this question as it gives me the opportunity to clear up these two points. A period of three years is indeed average, it might be slightly shorter or slightly longer. As to your second question, we virtually never sell out completely. The normal procedure is to sell as many shares as to recoup on the original investment, which means that the bank stays involved in the company, often to a substantial part. And we continue to guide them, but our people, who were originally put in on a five day a week basis, are gradually withdrawn as a proper management structure is build up. There have been instances where we sold out completely, but that only happened when we have overestimated the possibilities of a new product, when it became clear that successful introduction of the product would require much more research and more back-up than originally estimated. In those cases we try to provide for the continuity of the firm by placing part of the shares with institutional investors, who normally tend to be rather loyal to management, and sometimes too loyal.

Aspects of Technological Innovation

Dr. W.G. Evans
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Great Britain

The theme of this conference - "The management of technological innovation" will be examined in this morning's session through the medium of case studies of technological innovation. My colleagues on the panel will deal in detail with examples drawn from their particular industrial interests. By way of introduction I will proceed them, and attempt to illustrate some of the characteristics of technological innovation as may be seen in a rather wider range of cases drawn from several industrial sectors. The reason for including the case studies in the conference is simple. We want to ensure that the discussion later this morning is as close to the reality of our normal industrial environment as possible and that we do not become too enamoured of the theories of management as opposed to its practice.

Leonardo da Vinci lived from 1452-1519, and in that time produced a wealth of designs, plans, and products. They are all of historical importance but clearly the greater importance must be ascribed to the designs he actually transformed into 'hardware'. Though his design for a gas turbine as seen in Fig. 1 and intended for turning a spit to roast fowl is of historic interest, it is of little more than that, for it was not a practical design, - neither the materials nor the theory to convert it into an operating, everyday reality were available. It remained a mere interesting possibility until the technology had caught up with the design. Now thanks to the efforts of technologists we have turbines such as the one shown in Fig. 2, and it is this difference, the difference between possibility and achievement that should concern us this morning. We will be looking at the process through which ideas pass to become products, and the influence management can have on this process, and indeed the influence the product may have on the management process itself.

The primary characteristic of the innovation process (though it is a characteristic that is oftentimes overlooked) is that it is evolutionary in character. The products of today stand on the 'shoulders' or 'foundation' of their predecessors. Weaknesses in designs are eliminated, new features are added, functions are synthesised or separated, and gradually the product develops to its present form. The Daimler car series shown in Fig. 3, illustrates this process to a degree. Though the cars shown do not constitute the full range of products that have emerged from the Daimler 'stable' they do show strong line of continuity throughout. This view of products is of course at the 'macro' level. Here only the external generic features are evident and of course there are omissions. But nevertheless one surely recognises the fact that the products of today are developed from the technological, managerial, and social capabilities and assumptions that preceeded them. So as you examine the cases to be presented later this morning by my colleagues you will recognise that they will be speaking about products that have evolved and indeed are still evolving under the conflicting influences of crises and technological effort. We may take a still or 'snapshot' view here today of the product but we should not fail to recognise that it is nevertheless moving, and the prime mover in this process is the managerial effort guiding it.

It would however be incomplete to refer to the evolution of products on the 'macro' level only, for no doubt you all appreciate that the changes seen at the 'macro' or strategic level are the cumulative result of changes made at the 'micro' or tactical level. So by way of example one can contrast the automatic gearbox shown in Fig. 4, with its successor shown in Fig. 5. In the former case the gearbox had a 3 speed+reverse capability, whereas in the latter case one sees a much simpler design, clearly a more manufacturable design for the same unit where it now has a 4 speed+reverse capability.

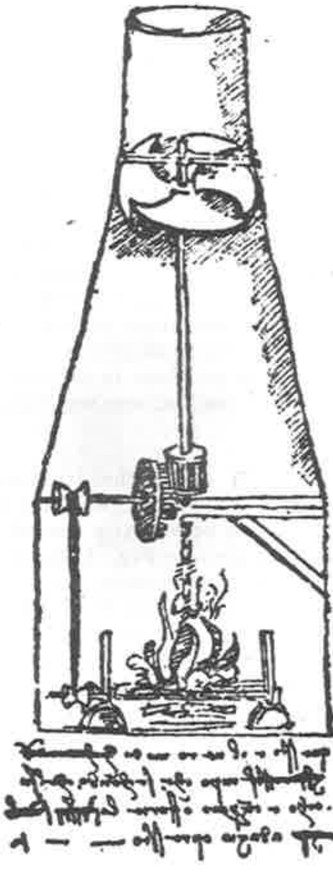


Figure 1

Figure 2

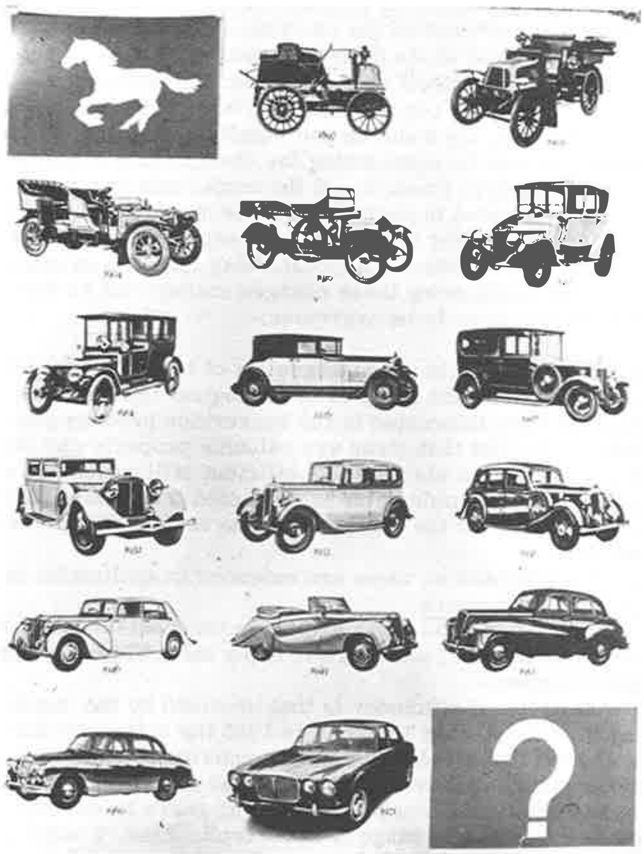


Figure 3

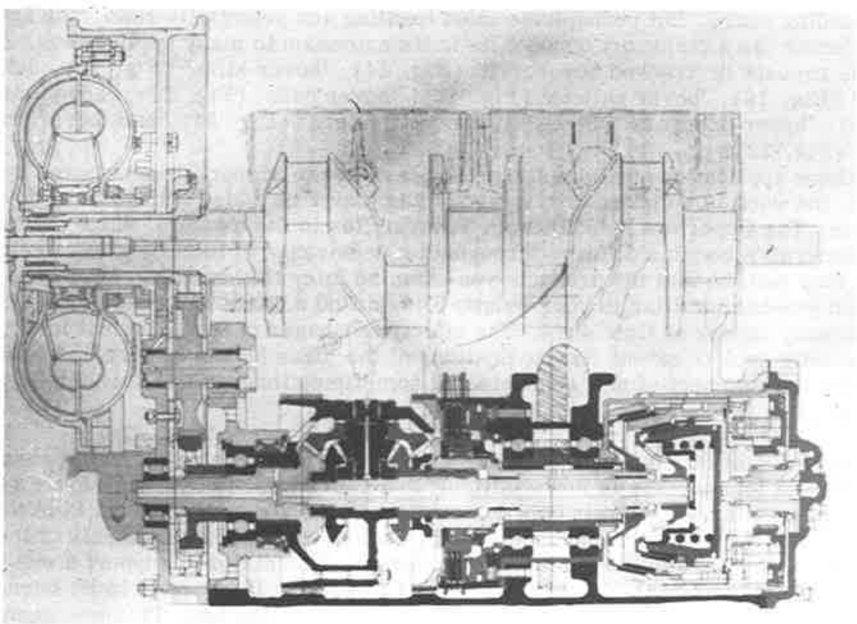


Figure 4

The micro development through which the gearbox went to gain its greater simplicity and capability was largely the product of the innovative efforts of one man who later commented that at this stage "the whole design seemed to sort itself out ". Of course it was not the design which sorted itself out, but rather the designer who realised the true function of each of the gearbox components, and who in the process of doing so extended the capability of the unit. No doubt as you watch the products and processes to be presented here today you will be considering the changes that could be made to them that would result in more effective products. If the conference is a success you will also no doubt leave here interested in posing this same question to yourself and your staff as you examine the products for which you are responsible. You will be interested to see how clearer thinking and a rational approach may lead to a greater 'fitness of purpose' of a product, and in achieving these changes managerial as well as technical impediments to progress may have to be overcome.

Since this conference is interested in the management of technological innovation it is hardly irrelevant to point out that the basis of technological innovation is the conversion of ideas into hardware. We are interested in the conversion process and also in the idea itself. We recognise the fact that ideas are valuable property and that we should be interested not only in them, but also in their efficient utilisation. We are interested in ensuring that the maximum possible value is extracted from the relatively few genuinely new ideas that appear on the industrial scene each year. This efficiency may be approached in two ways

(a) The efficiency manifested as ideas are extended in application throughout their initial conceptual framework

and (b) The efficiency manifested as ideas are transposed outside their initial conceptual framework to another, and there to apply them to produce radically new products and processes.

An example of the former type of efficiency is that provided by the 'hover concept'. Initially developed by Sir Christopher Cockrell in 1955 the coffee-tin and scales experiment he carried out showed that a relatively small quantity of ducted air could be used to support a large mass such as a hovercraft. The first model he made confirmed his rudimentary test results and throughout the succeeding years he devoted his efforts and those of many others to developing a range of hovercraft. Figs. 6 and 7 show his initial experiments and Figs. 8-13 just a few of the many hovercraft that were developed in the succeeding years. But perhaps the most exciting and potentially rewarding applications of 'hover' as a transport concept lie in its extension to many applications. The use of the concept in 'tracked hovercraft' (Fig. 14), 'hover kilns' (Fig. 15), 'hover mowers' (Fig. 16), 'hover pallets' (Fig. 17), 'hover pads' (Fig. 18), 'hover tanks' (Fig. 19), 'hover dredgers' (Fig. 20), 'hover trailers' (Fig. 21), and 'hover transporters' (Fig. 22).

Each of these applications utilised the principle of hover support demonstrated by Cockrell, but each in a different way, and it might also be added with varying degrees of success. The important lesson for us however lies in the extent to which the original idea of Cockrell's became diffused throughout a wide range of technological applications. It may well be that the products you examine later this morning, or indeed those with which you are familiar in your industry could find a much wider range of applications than may appear at first sight. The effectivemanager of technological innovation will constantly seek to extend the applications of the ideas he has available, sometimes through the development of new products and sometimes through the licencing of patent rights etc.

The second form of efficiency, that of transposing the idea outside its initial conceptual framework and into another is more difficult to achieve but can indeed be more rewarding and exciting. The hover concept extracted from the hovercraft of Cockrell was transposed into the medical field by Dr. J.T. Scales, and used as the basis of the hover-bed. Instead of using the hovering properties of an airjet to support a moving craft, Scales conceived the idea of using the jet to support the body of badly burned patients without them coming in contact with the material of the bed. This was seen as a

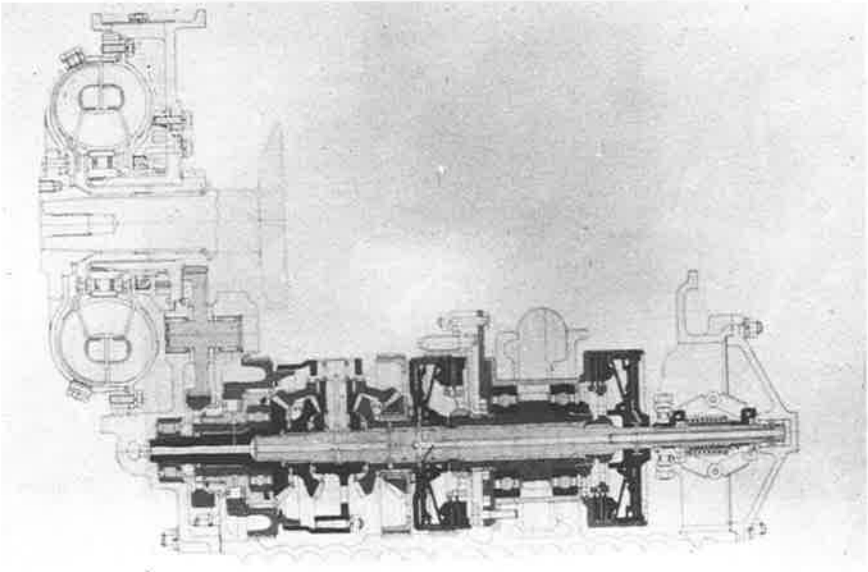


Figure 5

Figure 6

Figure 7

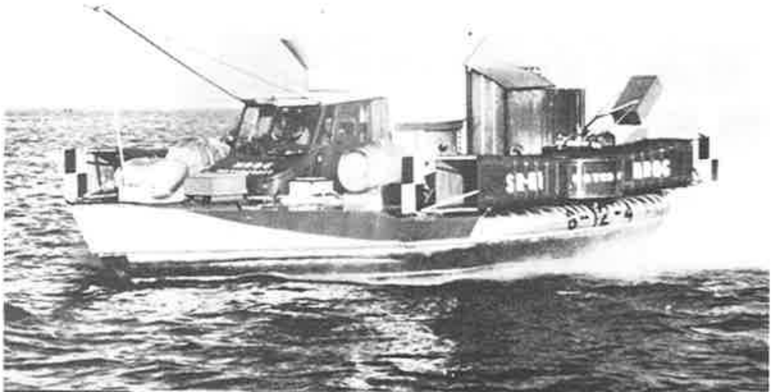


Figure 8

Figure 9

Figure 10

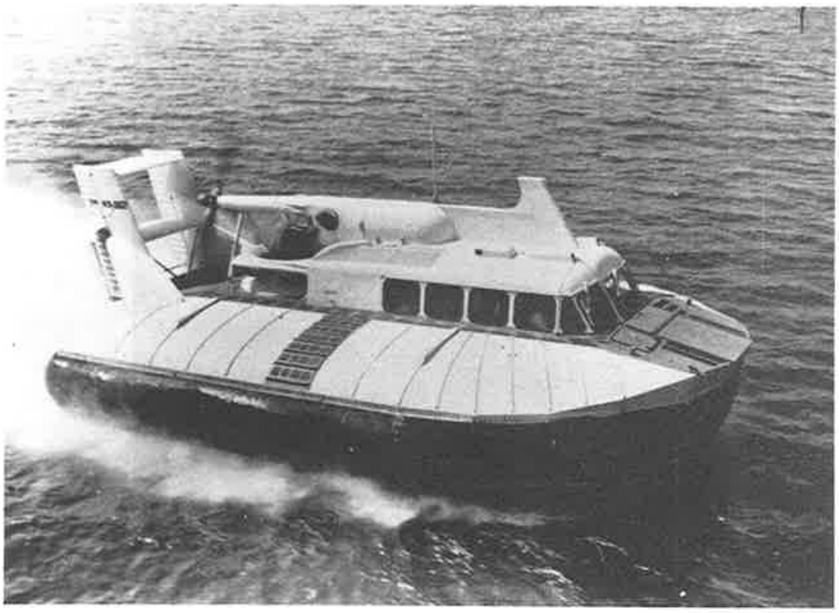


Figure 11

Figure 12

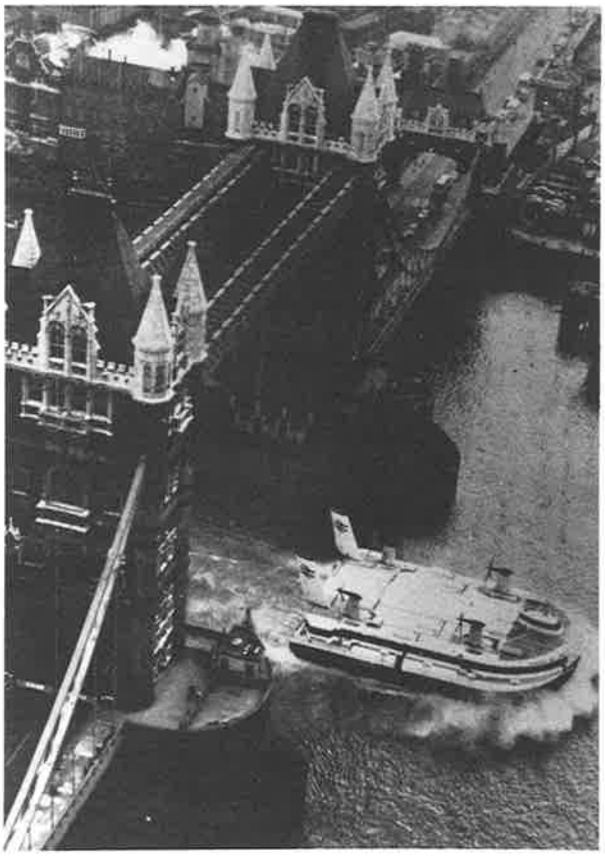


Figure 13

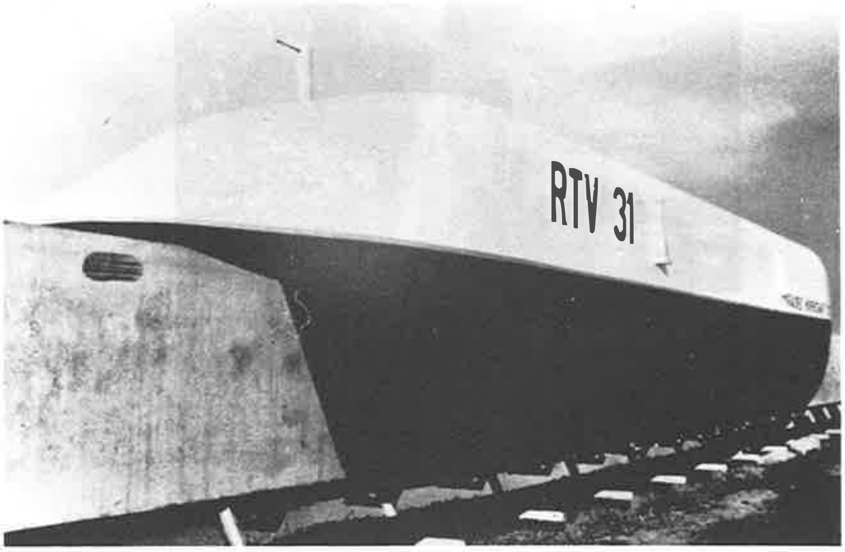


Figure 14

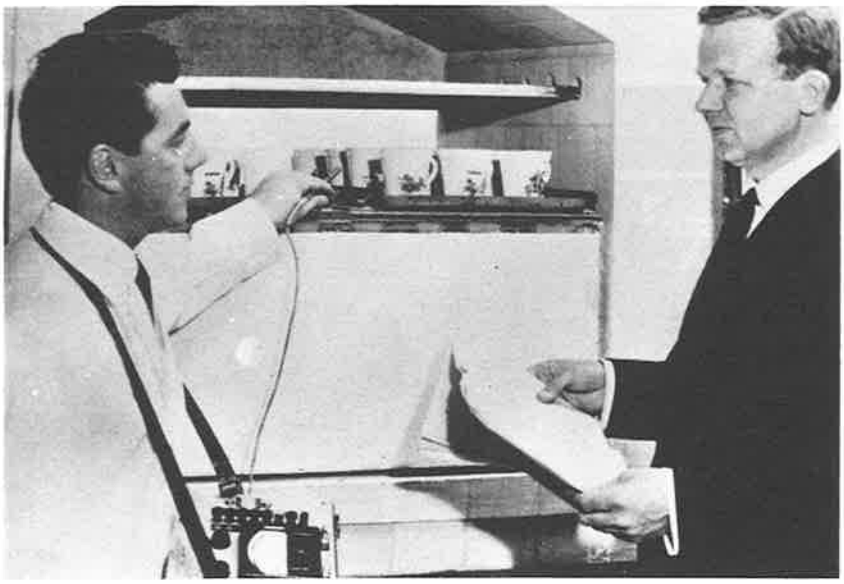


Figure 15

Figure 16

Figure 17

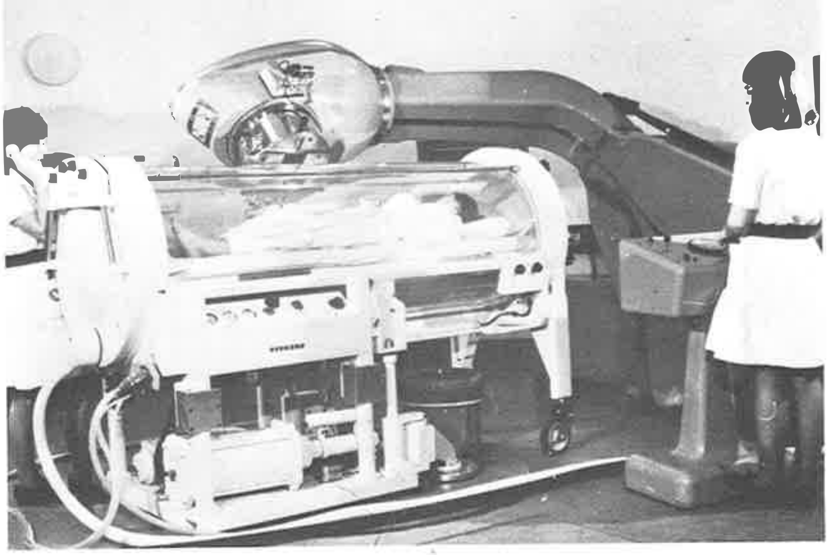


Figure 18

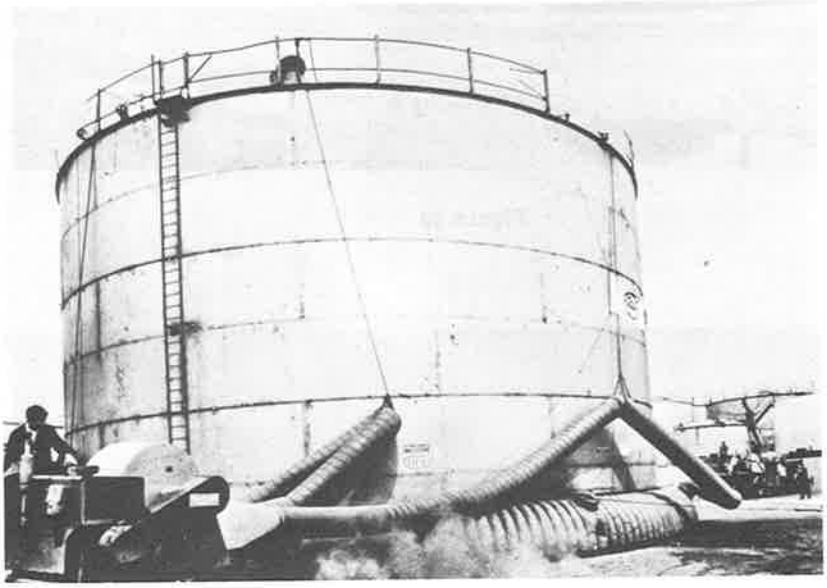


Figure 19

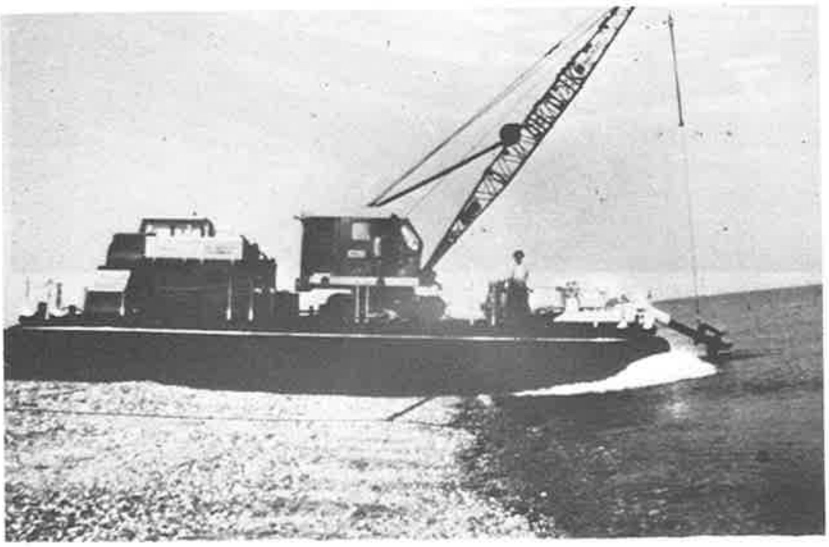


Figure 20

Figure 21

Figure 22

way not only of alleviating the distress caused by the burned areas coming in contact with the linen etc., and so impeding the recovery process, but also as a means of ensuring that the recovery took place in a continuously changing atmosphere of sterilised air. In Fig. 23 one can see the prototype of the hoverbed and the deforming effects of the airjets on an anaesthesised pig may be seen. Clearly the prototype was unsatisfactory from a clinical point of view, the patient could have suffered more damage from the jets than from the burns, but by a process of steady development through stages such as the 'coffin' stage shown in Fig. 24, the structure and sealing system of the hoverbed was developed to give the operational unit illustrated in Fig. 25. It is certainly worth mentioning that the successful development of the sealing system ultimately depended on the union of experience obtained by Mr. L. Hopkins in the development of hovercraft skirts such as those for the VT-001 hovercraft with the design of the hoverbed as evolved by Dr. Scales. Another example of the successful transposition of an idea already developed in one field into another is provided by the 'Lancaster' bomber aircraft. The undercarriage leg of the Lancaster was developed by Dowty Ltd. and many of the units were made during and immediately after the World War II. By transposing the undercarriage legs to the mining industry the units (though slightly modified to increase their load capacity) became hydraulic pit props. Fig. 26 shows a cross section of a typical aircraft leg unit and the pit props developed from them may be seen in Fig. 27. Many thousands of these props have been built and provided a major advance in mining techniques. Later the prop unitswere ganged together as shown in Fig. 28 to provide self-advancing roof supports for the mining industry. Another and related example of this efficiency in the use of concepts may be seen in the transposition of aircraft undercarriage technology to the cable-laying industry. The traditional method of laying cable from ships had the serious deficiency of being an intermittant operation. The diameter of the cable increased substantially at the point where the repeater amplifiers were located. To continue laying the cable required removing it from the feed mechanism playing it out manually, and then reinserting it into the feed mechanism. By adopting aero technology it was possible to develop the cable laying machine shown in Fig. 29. This permitted the cable to be played out continuously irrespective of the diameter of the cable passing through the machine. Once again one can see the value of transposing technology from its customary field of application to a new area, and it is clear that substantial efficiencies can be achieved in the use of technology provided one is willing to examine the conceptual content of products in a fundamental and critical way.

Technology is an expensive business and the cost in manpower and financial terms of acquiring a technological capability can often be extremely high and can never be neglected so we should be concerned not only about the technology, but also the efficient use of companies technological capabilities. If an organisation has invested effort in learning how to fabricate a complex structure, it is obviously in its interests to make maximum and efficient use of this capability. J & S Pumps Ltd. developed the technological capability to manufacture canned-motor-pump units of the type shown in Fig. 30 and achieved a major sector of the market for these specialised products. By using that same technological capability (experience with machining impellers, sealing shafts and making pressure tight electrical connections etc.) to produce the well-head submersible generator unit shown in Fig. 31 for use with off-shore gas wells, the company extended its product range in a most interesting manner.
We tend to emphasis the importance of the technology but of course we should also recognise the importance of getting the technology to where it can be used. Here in Holland the distinction between the conditions required for successfully growing a seedling and growing a plant will be well appreciated - oftentimes very different treatment and soils are required for the two phases of the life of the same plant. So its interesting to pay attention to where the idea embodied in a technological development comes from. In the case of the Mirrlees K-Major engine series, the exhaust valve assemblies shown in Fig. 32, were given an increase of life from 500 hours to 3,000 hours largely due to a very simple development made by a shop-floor development engineer. He suggested the cyclical pulsing of lubricating oil pressure on the valve stem to prevent both the in-

Figure 23

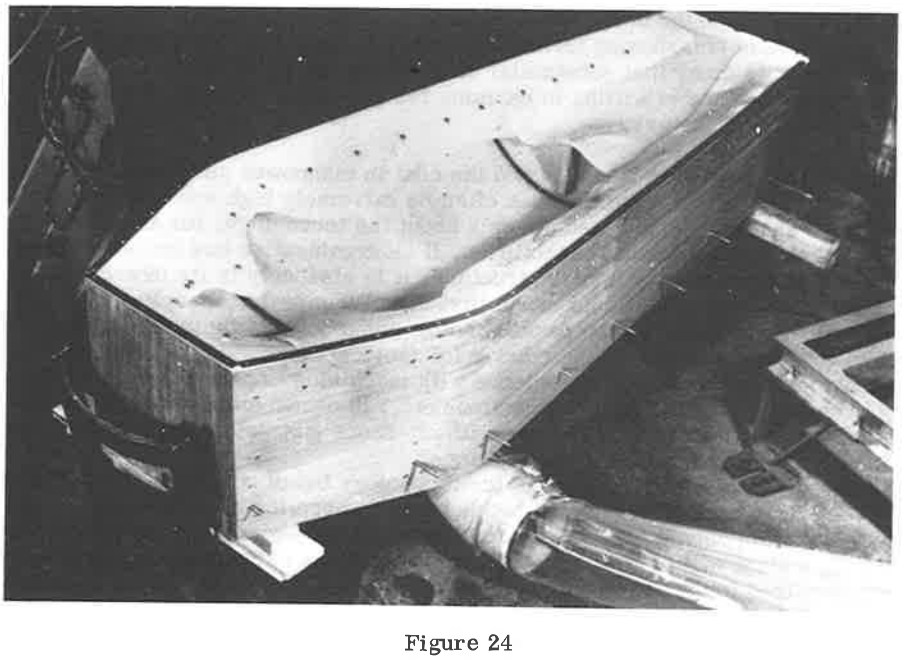


Figure 24

Figure 25

Figure 26

Figure 27

Figure 28

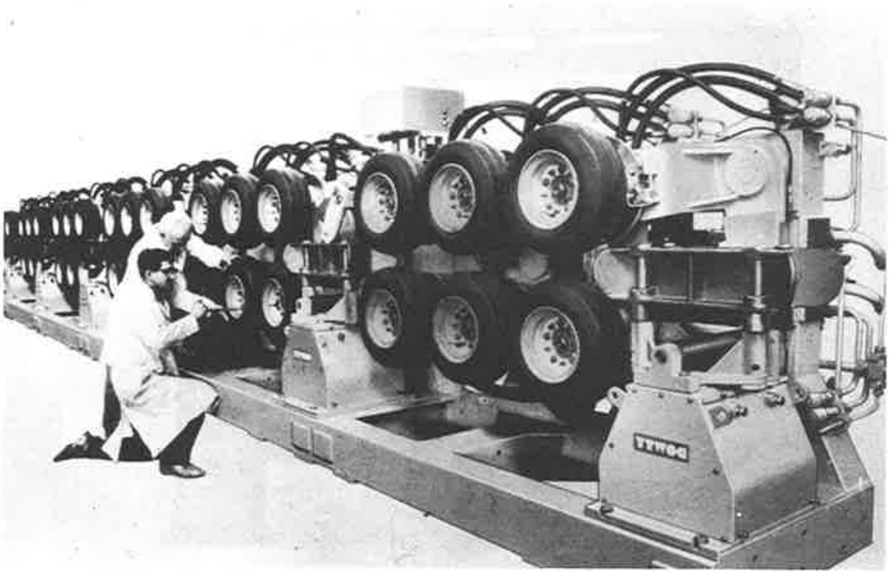


Figure 29

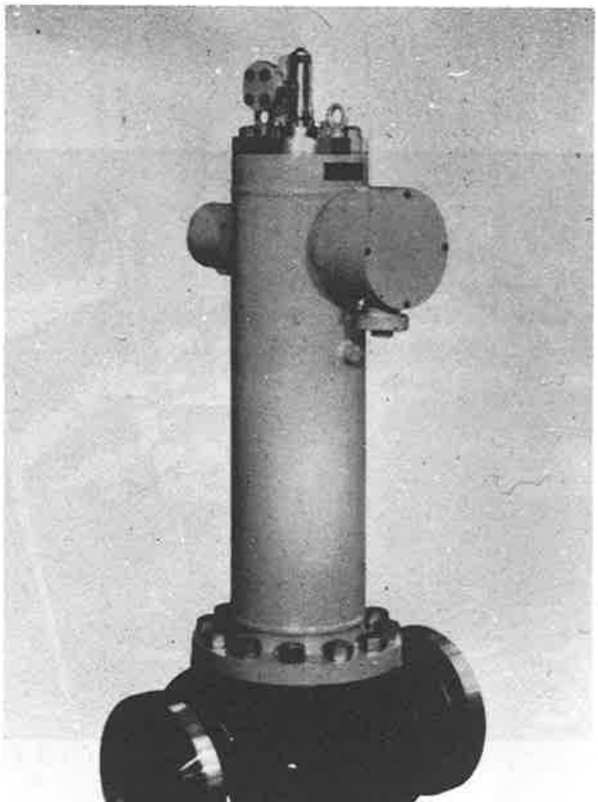


Figure 30

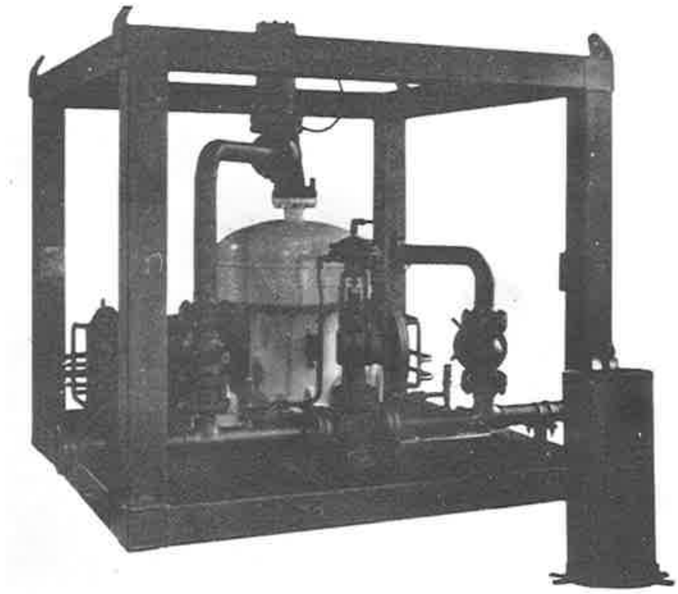


Figure 31

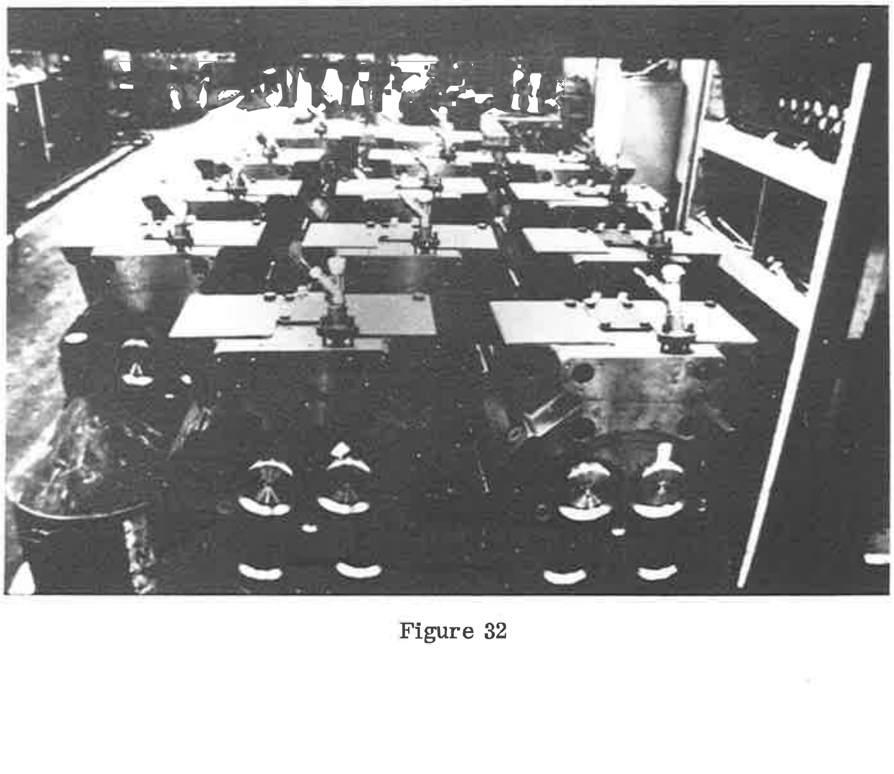


Figure 32

gression of corrosive gases into the stem guide, and the egression of lubricating oil onto the stem when exposed to the exhaust gas stream. The fundamental radical development of the superstructure for the Vosper fast patrol boats, the difference seen between Fig. 33 and 34, for craft using gas turbine engines, came from a senior member of a Government naval laboratory working in an advisory capacity to the fast patrol boat manufacturer. In the case of the Colchester Lathes Company's 'Flowline' system of assembly line manufacture of lathes, the fundamental idea, that of supporting the assembly bases on a series of oil pressurised pads was taken by the Managing Director of the Company from a report by one of the Company's junior engineers prepared during a training year at the (then) College of Aeronautics in Cranfield. Fig. 35 shows the support and raft assemblies and Fig. 36 shows the 'flowlines' in operation. Finally, if one examines the history of the 'Gaugemeter Automatic Gauge Control' system for the control of strip metal thickness one finds the fundamental ideas - those of using the roll as its own micrometer, and of controlling thickness by controlling both load and tension on the strip, being developed and proved within the British Iron and Steel Research Association and later being transferred together with most of the original development team into industry. Fig. 37 shows an outline of the basic system and Fig. 38 shows the major advance the system conferred with respect to quality control in the rolling operation. It is I think a good example of the wisdom of taking not only the 'seedlings' but also the 'gardener' to the final location of the 'plant'. I hope you will pay due attention to the transfer mechanism and that you will be stimulated to outline your views on this aspect of the management of technological innovation in the discussion.

The importance of the sector which I like to refer to as 'service technology' will be appreciated by you all. By this I mean the developments which of themselves are not part of the product but enable it to be produced. Such a classical development is that of electron beam welding which has enabled significant advances to be made in many products such as the welding of 'Stellite' rings onto the valve bodies of Mirrlees K-Major diesel engines as seen in Fig. 32, and the welding of the bevelgear clusters of Automotive Products Ltd's automatic gearbox as seen in Fig. 39. Later this morning we will hear more about this particular aspect of technological innovation. Some of you may wish to comment on the mechanism of detecting and inducting these 'service technologies' into a firm to expand its technological capability.

You will have in your minds the importance of obstacles to the innovation process the most important of which seems to me to be the propensity we engineers have for getting 'set' on our particular solutions to problems or our conviction that unless something is done <u>our</u> way it cannot be done at all. So for example when the designer of a well known small diesel engine asked a piston manufacturer to produce a piston (Fig. 40) with a length/diameter ratio of 1:1 as opposed to the more conventional 1:1.29 the manufacturer at first refused on the grounds that it just could not be successful. The designer persevered the piston went into production and many thousands of these successful engines have now been produced. To persuade the chief engineer of a company designing an automatic gearbox to abandon the use of double-cone clutches (Fig. 41) it was necessary to get a directive from the company's board of directors, - the reason was simple, they represented an investment of over two years development effort by the chief design engineer and the company's clutch material suppliers. The chief engineer was understandably reluctant to abandon the concept, especially since he had been awarded a patent on their application in this circumstance. There is another danger which I think it is relevant to mention and this is the danger of letting the 'sweetness of complication' cloud our appreciation of the 'simplicity of success'. Often our academic training teaches us the desirability of attaining prestige as designers and (almost subversively) teaches us to equate prestige with complexity. There is a certain attraction for us in being able to say 'yes that product is complex and I was able to design it'. Studies of real industrial problems that have been successfully overcome however give us a great deal of respect for the designer who has the ability to solve a complex problem in a simple manner. Such an example of classical simplicity is the invention of

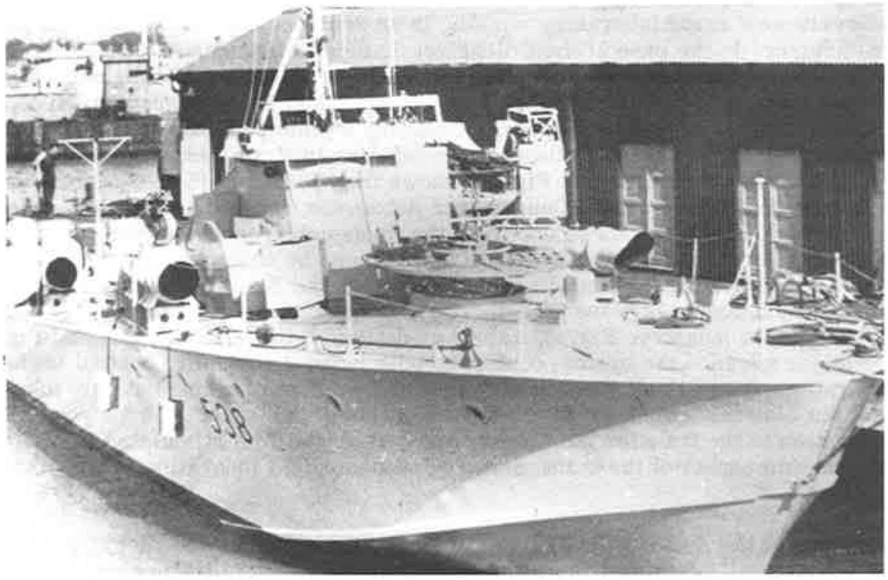


Figure 33

Figure 34

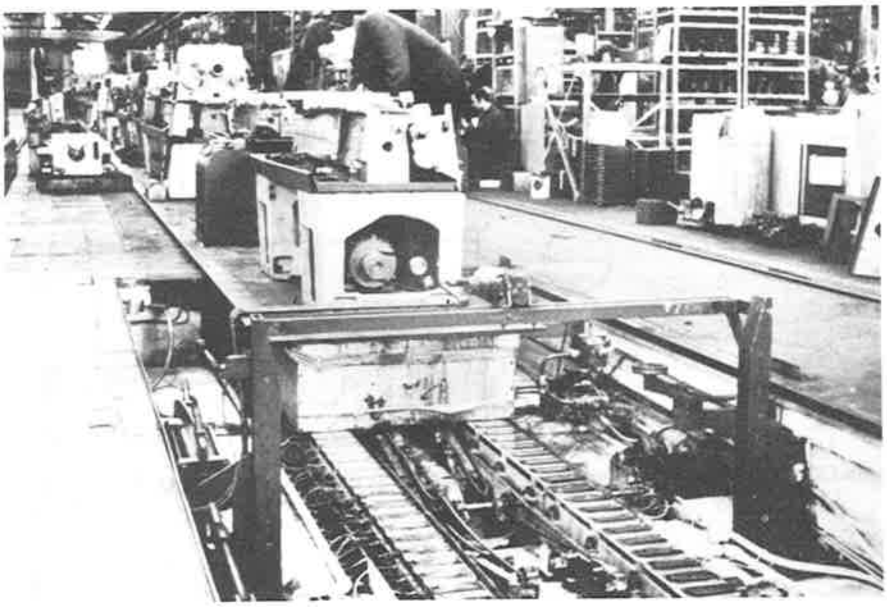


Figure 35

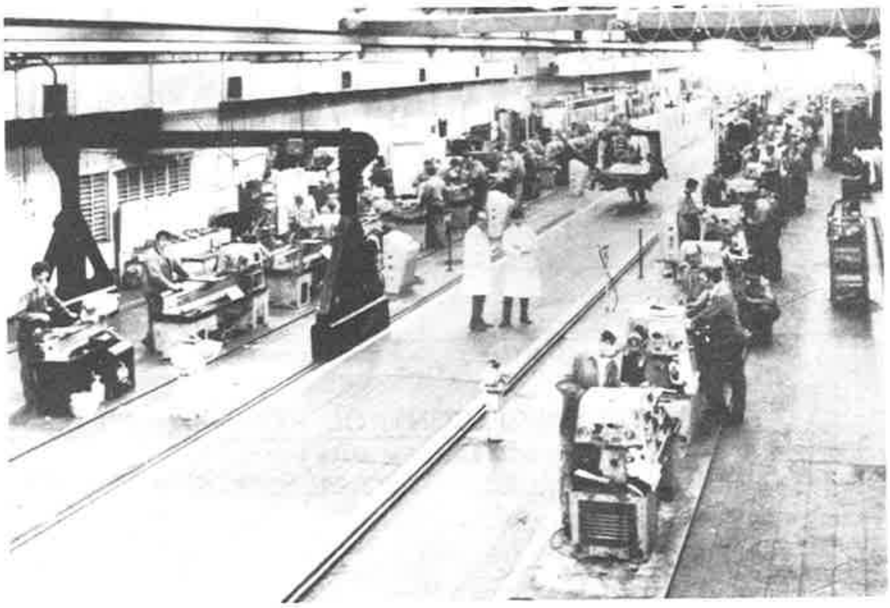
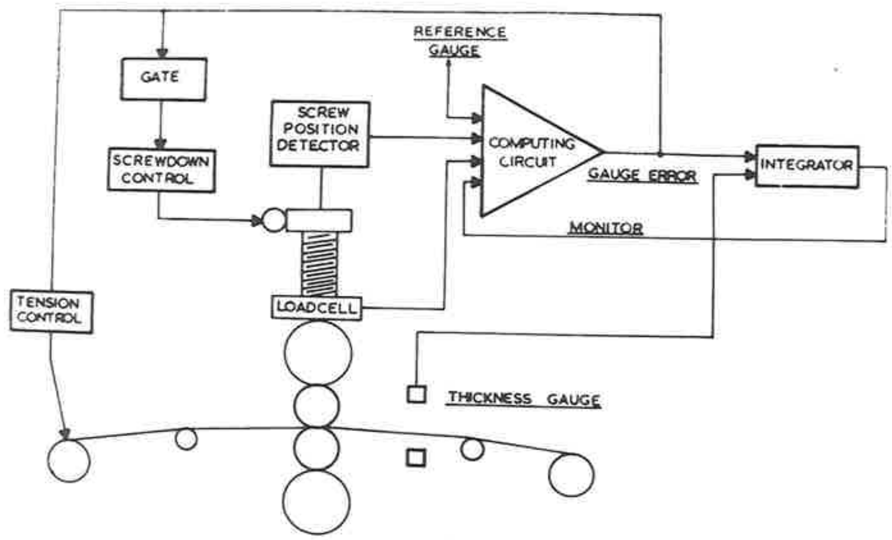
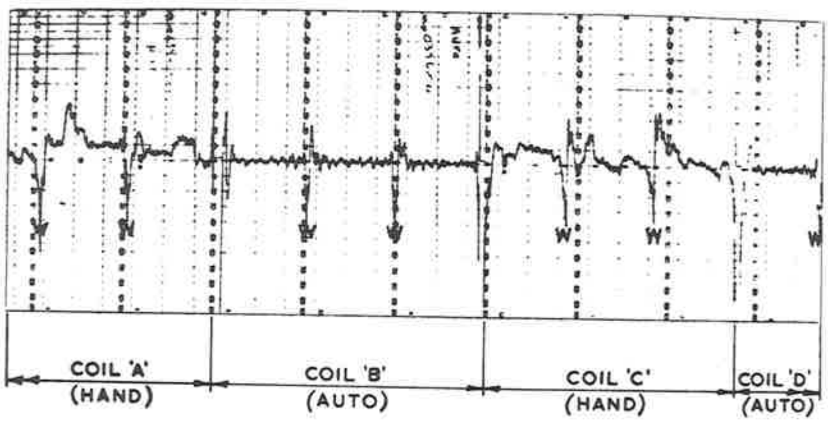


Figure 36



BLOCK DIAGRAM OF GAUGEMETER A.G.C. SYSTEM FOR COLD REVERSING

Figure 37



AUTOMATIC GAUGE CONTROL PERFORMANCE
(COLD TANDEM MILL)

W = Weld.

Vertical Scale : 100 ≡ 0·005 inches ≡ 0·127 mm.

Figure 38

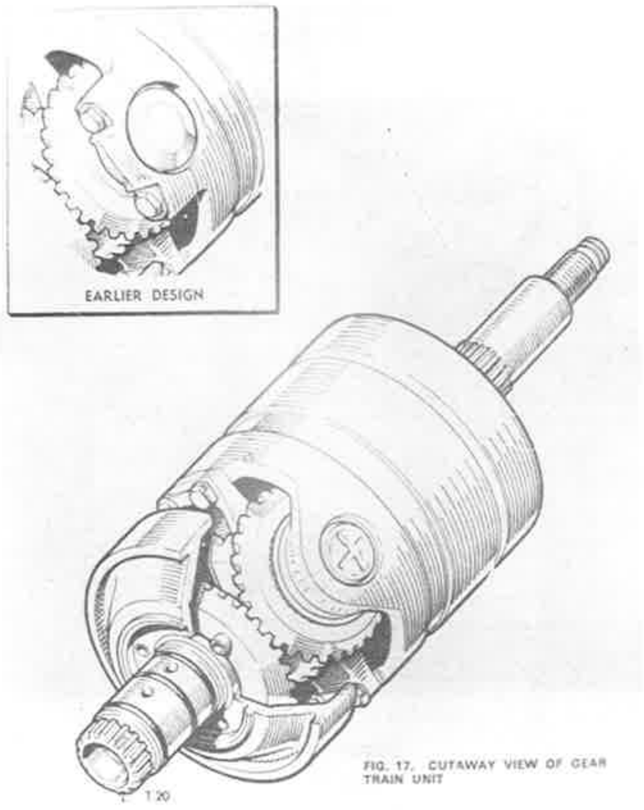


Figure 39

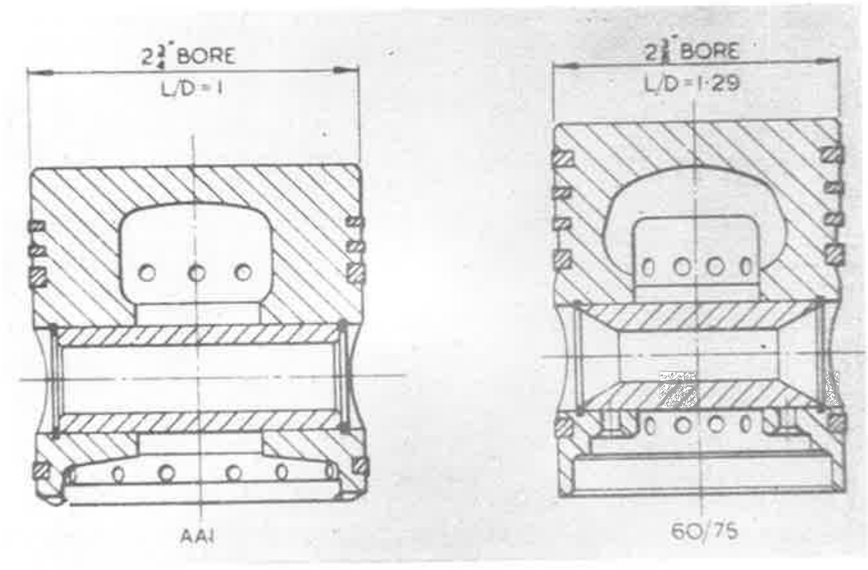


Figure 40

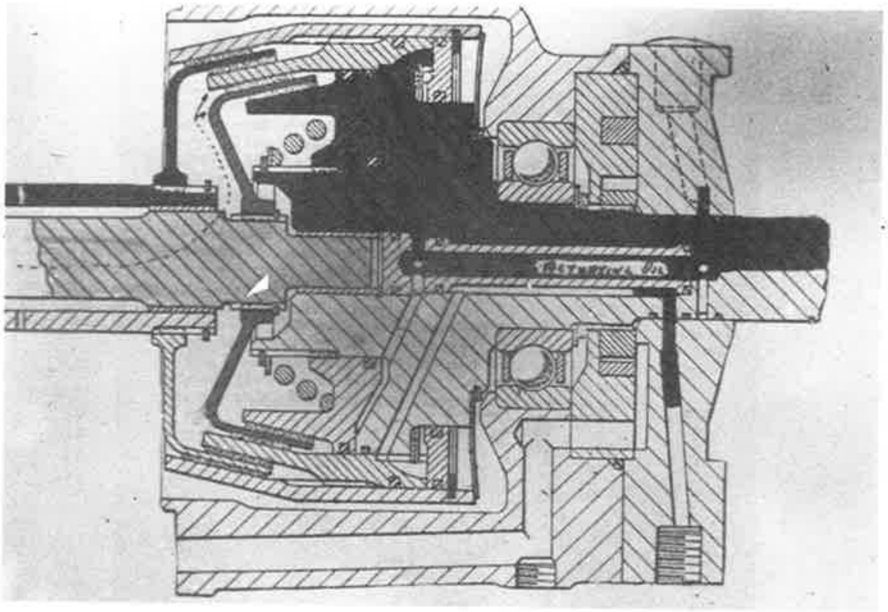


Figure 41

Vee hangers by Sir Gilbert Roberts to eliminate oscillation of the deck of aerofoil type suspension bridges. Fig. 42 shows the conventional vertical hanger configuration for suspension bridges, Fig. 43 shows the vee hanger formation adopted for the Severn Bridge and in Fig. 44 one can see the aerofoil deck sections being assembled to form the welded deck. The invention moved into the realm of innovation after it was incorporated into the Severn Bridge and the Bosporous Bridge, and it will also feature in the Humber Bridge which will become in 1976 the longest single-span suspension bridge in the world.

We would be glad to hear the views of those who would like to comment on the process of defining the need to which technology has to respond. All too often one hears the criticism that a product was technically interesting and advanced but that it was not needed by a market. So we could consider the need for better market analysis methods and perhaps more significantly the interpretation of these analyses to yield reasonable guidelines for decision taking. Under this general area too we could consider the inter and intra company difficulties that arise in responding to market needs and particularly that one of matching the timescales of response of different sectors to stimuli. Many of us will no doubt be considering how one can more effectively assess the social political and economic acceptability of the technical solutions proposed to meet needs and you may wish to comment on these points in the context of the cases presented here this morning or perhaps even by reference to other cases with which you are familiar.

Finally I would like to draw your attention to the point which can so easily be forgotten at a meeting such as this - that not all technological developments succeed. They may appear as successful innovations for some time, but it is really only after a substantial period of time that we can judge their success or failure. We might recall the Tacoma Bridge, the Ferrybridge cooling towers (Fig. 45), or the Uskmouth turbine disaster (Fig. 46) as examples of engineering innovations that were thought to be all right at the time, but did not quite live up to expectations.
I trust this will not be the fate of the other products you are to hear about this morning.

Figure 42

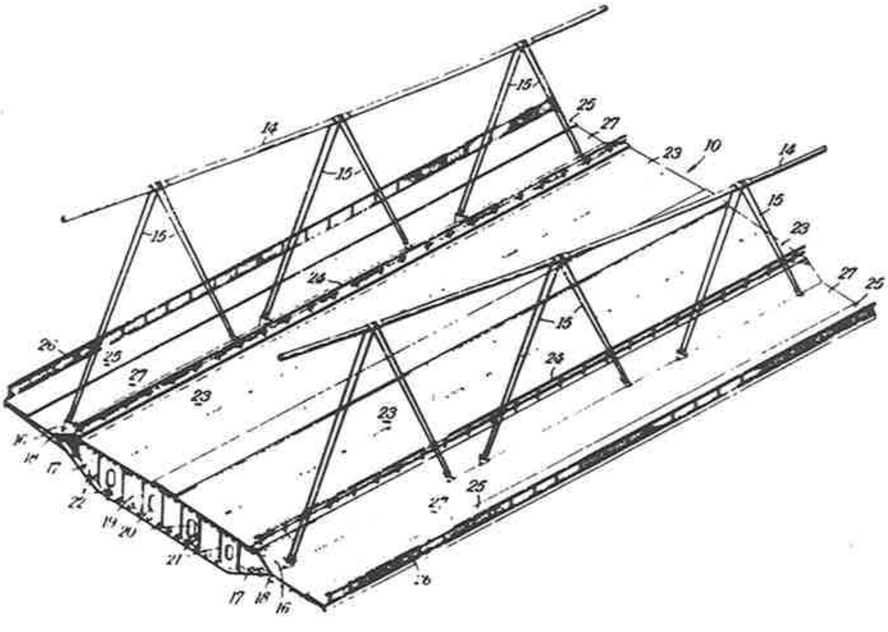


Figure 43

Figure 44

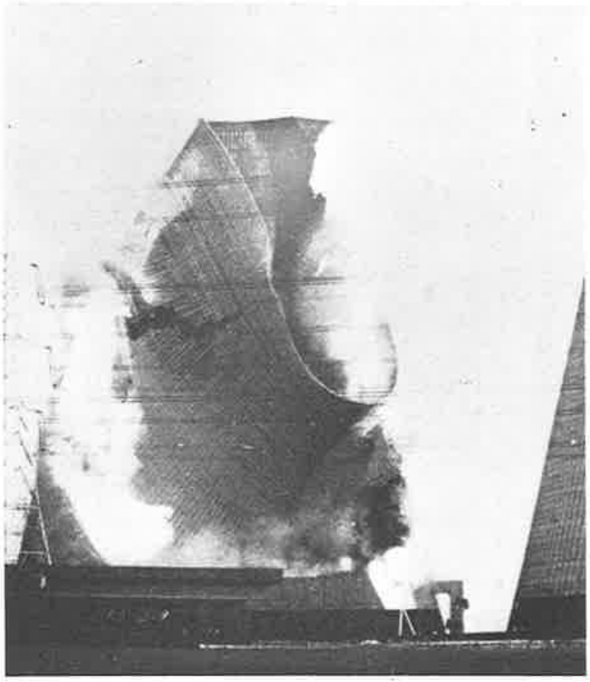


Figure 45

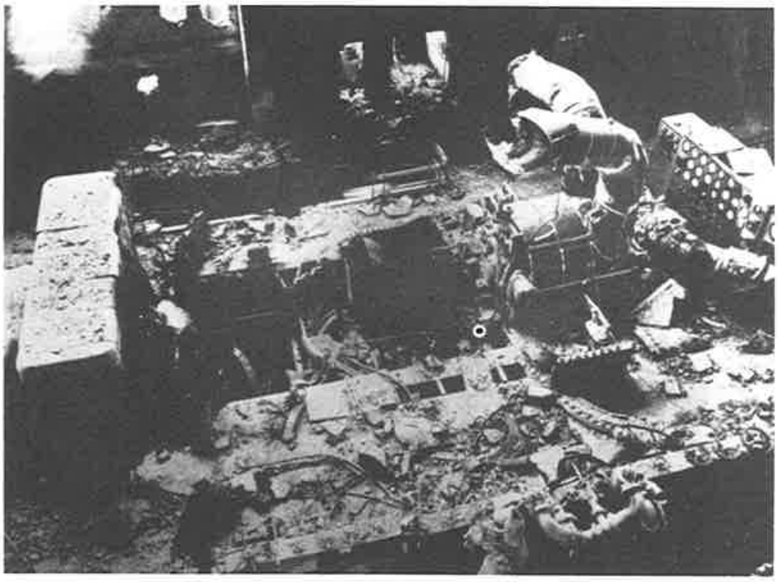


Figure 46

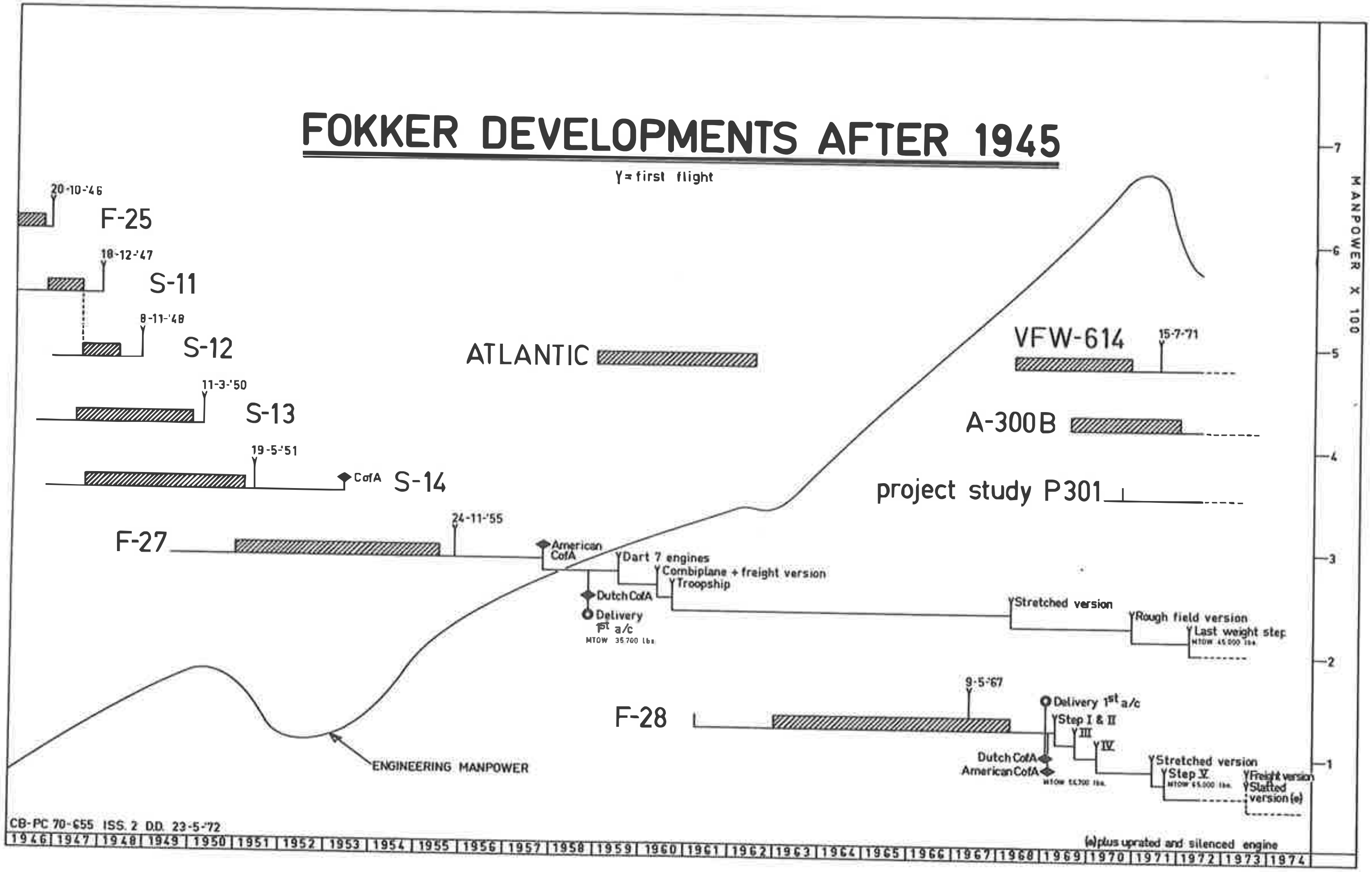
The Fokker Friendship

Dr. J.H. Greidanus
Fokker - VFW N.V.
Amsterdam

Gentlemen, I have been wondering if the development of an aircraft is a very suitable subject to the purpose of this congres. The development of an aircraft is a very large process; it is in many respects very extreme and exceptional, it covers a long time, it is very complex, it involves tremendous risks, and it requires financial means which are so large that there are at this moment no companies in Europe, who can on their own funds proceed to the development of new aircraft. We are combining industries and we are requesting the support of governments in order to keep this type of work possible. It is of course also difficult in a very short time to give a reasonable insight in how such a process works, but I will try to give you a survey at the hand of a few slides on the organization of such a process in time. I will try to give you an idea of the sources of the complexity and the nature of such a development process. I will briefly touch the exceptional relation between research and development and I will also present the process to you in terms of money.
Finally I will refer briefly to marketing and market analysis aspects. I will only be able to mention the most important things and I will use the F 28, as the example of choice, rather that the F 27 as announced in the program.

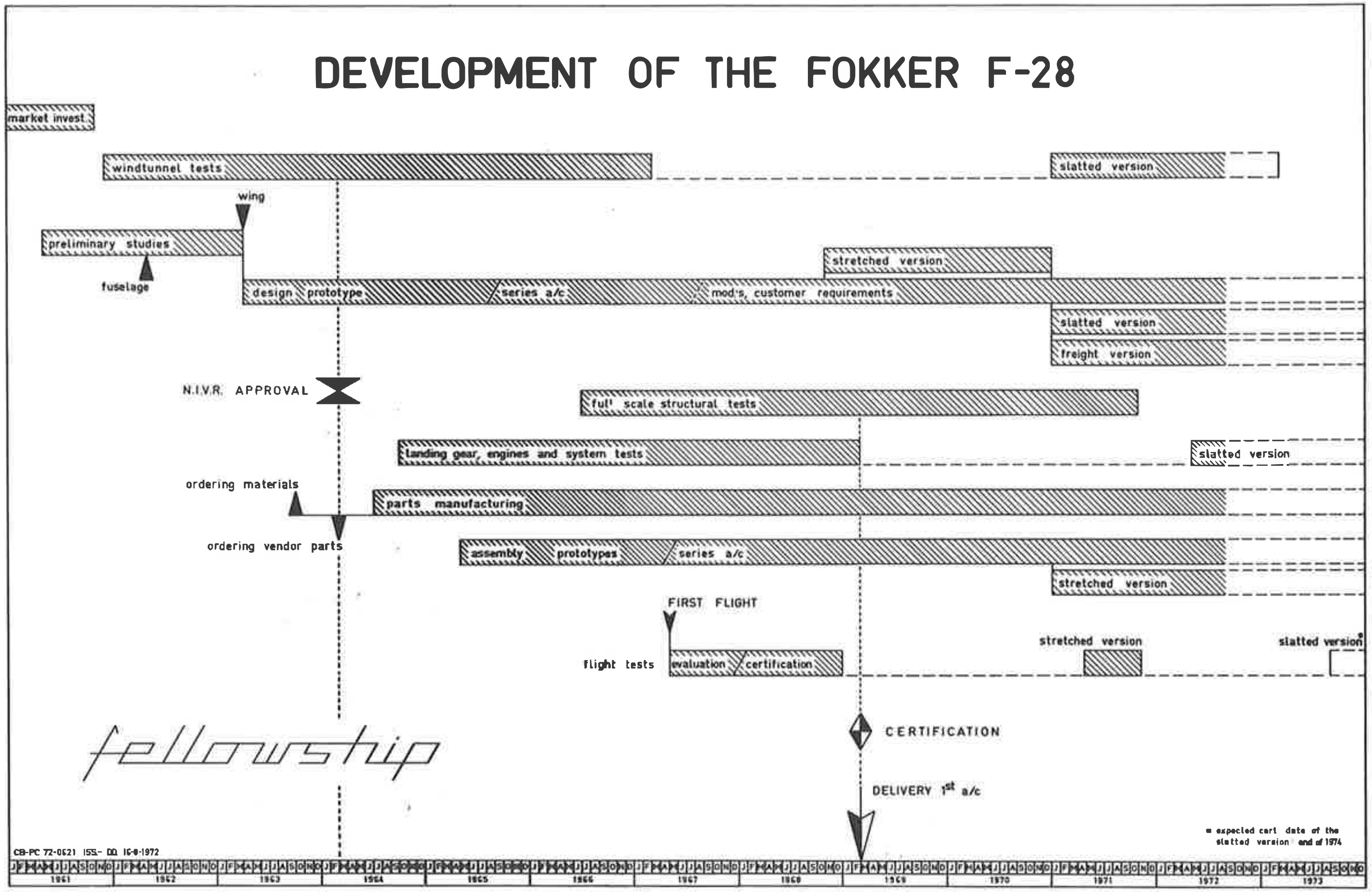
Fig. 1 presents a survey of all the developments of the Fokker company since 1945. The time-scale extends a few years into the future and so at its far end contains a few developments which are in course of progress but not yet ready.
What I should like to show in this figure is, that we started thinking about the F 27, which is an airplane which I presumably don't need to describe to you, in 1949. The first phase is entirely preparatory. The actual development work started in 1950, the first proto-type flew in 1955, the certificate of air-worthiness obtained in 1958. Immediately thereafter the first airplane was delivered to the first customer. This was the end of what could be called the development of the basic airplane. In actual fact however the work proceeded continuously with the development of additional variants and versions of the airplane. In the early sixties the work slowed down, but around 1964 we started designing a stretched version of the airplane, and slightly later a rough-field version. As late as 1972 we pushed the aircraft to its present relatively high weight limitations.
This may show that, if such a process is to be planned, if all its facets and implications are to be foreseen, then a time span of more than 20 years has to be considered. And the review performed may even be incomplete, for the airplane concerned is still in production and further developments are not completely excluded.
As shown, Fig. 1 also presents the F 28 process. We started thinking about this airplane in 1960. This could be called the beginning of the conceptual and preparatory phase. Actual development work started in the beginning of 1963. The first flight was in 1967, the certification and delivery of the first airplane early in 1969. Far more rapidly than in the case of the F 27 next development steps were initiated. The concerned a series of weight limitation increases and a stretched version of the airplane. At this moment we are working on a version with an improved wing (a wing with nose slats). It is totally impossible to guess how and when this process will end. If the airplane sells well, it is sure that we will go on developing it, and this may easily go on for some 10 years or more. Then the F 28 may also cover a time span of 20 or 25 years. You might suggest to leave out of account all developments following the creation of the basic airplane and perhaps consider them as less important, but it is really not justified, for the success of the whole enterprise is quite critically dependent on the steady continuation of the development. Stopping it would lead to a premature end of the whole program.
Fig. 2 again refers to the F 28 and illustrated some detail of the basic development

Fig. I



FOKKER DEVELOPMENTS AFTER 1945
Y = first flight
20-10-'46
F-25
18-12-'47
S-11
8-11-'48
S-12
11-3-'50
S-13
19-5-'51
CofA
S-14
ATLANTIC
VFW-614
15-7-'71
A-300B
project study P301
F-27
24-11-'55
American CofA
Dart 7 engines
Combiplane + freight version
Troopship
Dutch CofA
Delivery 1st a/c
MTOW 35 700 lbs
Stretched version
Rough field version
Last weight step
F-28
9-5-'67
Delivery 1st a/c
Step I & II
III
IV
Dutch CofA
American CofA
Stretched version
Step V
Freight version
Slatted version (e)
ENGINEERING MANPOWER
MANPOWER X 100
7
6
5
4
3
2
1
CB-PC 70-655 ISS. 2 D.D. 23-5-'72
(e) plus uprated and silenced engine
1946 1947 1948 1949 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974

Fig. 2



DEVELOPMENT OF THE FOKKER F-28
market invest.
windtunnel tests
slatted version
wing
preliminary studies
fuselage
stretched version
design
prototype
series a/c
mod's, customer requirements
slatted version
freight version
N.I.V.R. APPROVAL
full scale structural tests
landing gear, engines and system tests
slatted version
ordering materials
parts manufacturing
ordering vendor parts
assembly
prototypes
series a/c
stretched version
FIRST FLIGHT
flight tests
evaluation
certification
stretched version
slatted version*
CERTIFICATION
DELIVERY 1st a/c
fellowship
* expected cert. date of the slatted version end of 1974
CB-PC 72-0621 ISS.- DD. 16-8-1972
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973

process. This survey starts in 1961 with market research and preliminary studies. At the end of that year we started with the first wind tunnel tests. These tests continued almost without interruption until 1967. A next phase began in 1971 on behalf of further aerodynamic developments to the airplane (the slatted wing version).
The actual design, that is the preparation of the first design drawings, was started in 1963. This work again represents an almost continuous process. The first phase leads to the prototypes. The next operation concerns the production airplane. This again is followed by the design of modifications resulting from flight and other tests. As soon as the basic airplane was ready, work was initiated directed at weight limitation increases and a stretched version of the airplane. At this moment a slatted wing version, to which I have already been referring, is in course of progress.
The whole process of course required very careful organization. If it is not organized very carefully, then surely all financial limits and budgets will be surpassed. It is particularly important not to loose time. So, as soon as some design drawings are ready, manufacturing of parts concerned must immediately be started and each next phase must be connected up to the preceding one as precisely and as quickly as possible in order to have the airplane flying at the earliest possible moment.
As soon as some parts are available, they must be inserted in the appropriate sub-assemblies, which subsequently are as quickly as possible combined to the airplane itself. As soon as the first airplane is ready - this was with the F 28 in May 1967 - test-flying is started. In parallel a long series of full-scale structual tests is being organized, which stretches over many years. These tests are essential to the development of any airplane, for the structure of an airplane has to be proven with respect to static strength, fatigue strength, fail safe properties, and so on. The flight testing generally consists of two parts. The first phase is roughly speaking an evaluation phase, in which it is being verified whether the objectives set have been reached, the specifications met, and secondly, as soon as it is sufficiently certain that everything is O.K., certification tests are being organized. The certification is an official operation, an official confirmation that the new airplane meets all requirements determining its airworthiness.
Fig. 3 gives an again different break-down of the development work. It shows what kind of functions are involved and the percentage of man-hours in each category. The work is first divided into engineering, 21% of the whole, design drawings 20%, production preparation 5%, tooling development and preparation 11%, tooling manufacturing 16%, production 23% and a miscellaneous part (licenses, liaison, handbooks) 4%.
Within engineering and design a further break-down is shown. The largest part of the engineering work is "strength", 22,5%. Aerodynamics takes 10,5%, the engineering of the various systems of the airplane 22,8%, the large testingwork (exp. dept.) 14,5%, and so on. The production refers to the prototypes and to all the hardware required for the test programs only. In the design drawing office, the structure requires 36% of the total work, the installations (mechanical systems, instrumentation, etc.), 36%, the electric and electronic provisions 18%. The remaining 10% is required for the technical administration. All this however, refers to Fokker-VFW only. In actual fact the program was international. There were three partners, Short Brothers and Harland of Belfast, Hamburger Flugzeugbau of Hamburg and Vereinigte Flugtechnische Werke of Bremen (presently VFW-Fokker, Bremen).
Fig. 4 contains some data referring to these participations in the development. It clearly shows that in addition to Fokker's own work much was done by the partners. The participations concerned were not necessary because Fokker could not have done all the work herself. They have industrial-political reasons. The project was so large that we needed more resources than the Netherlands could be supposed to bring up. Moreover partners were supposed to strengthen the program politically and to facilitate access to certain markets.
In addition to partners, fig. 4 also mentions the valuable and significant participation of our national laboratory, the N.L.R. This took care of the wind tunnel testing and of the major part of the flight test instrumentation. They also performed many detail tests and a full scale fatigue test.
In the next figure, figure 5, the whole process is shown in terms of money. On the

Fig. 3

development hours F28 FOKKER

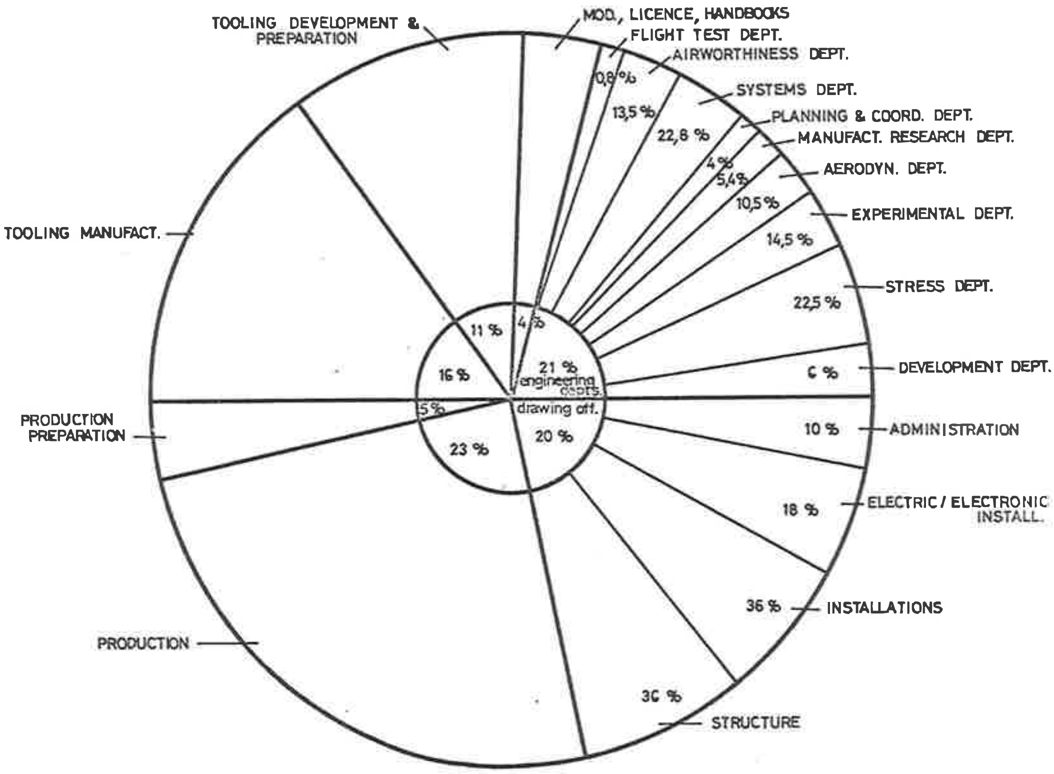


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Fig. 4

development hours F28 TOTAL

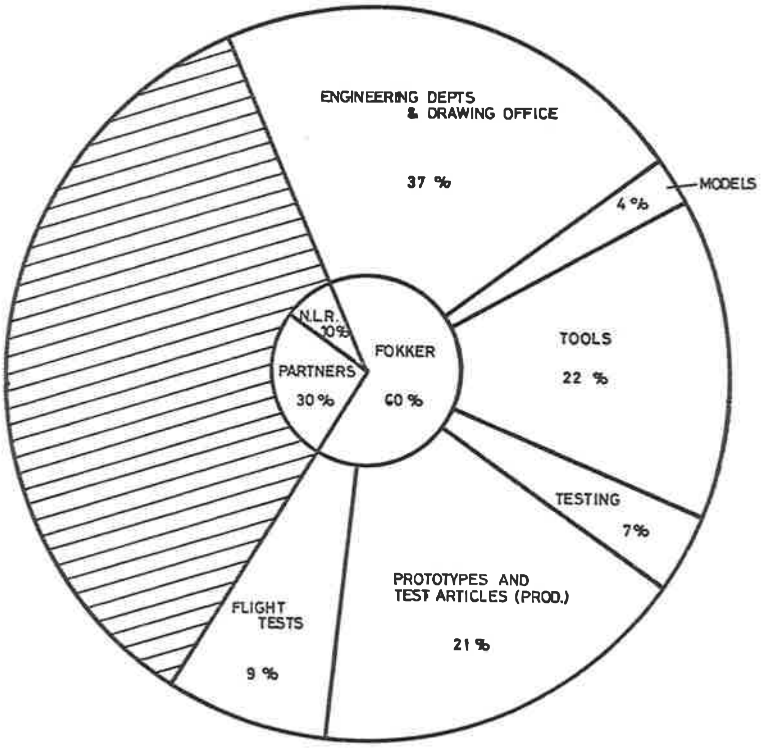

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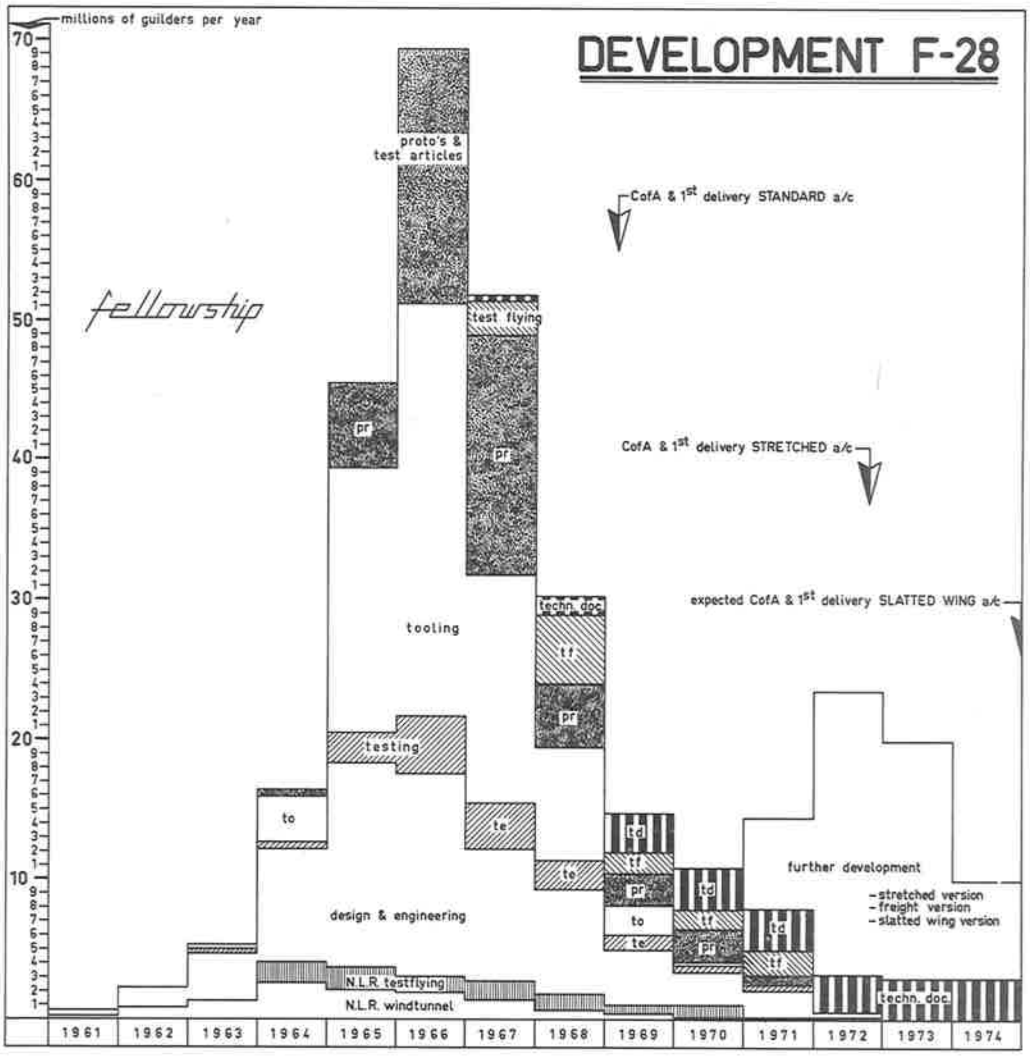
Fig. 5



FOKKER-V.F.W.	Fl. 150.1	million
N.L.R.	Fl. 20.0	"
SHORTS	Fl. 40.8	"
V.F.W.-FOKKER	Fl. 26.9	"
M.B.B.-UH (H.F.B.)	FL 27.2	"
total	Fl. 265.0	million
further developments	FL 50.5	million

vertical axis are millions of guilders per year. The process again starts in the early phase of the conception. The amount needed in the first year was only half a million. But the amount of money needed is rapidly increasing. A first addition is needed for the wind tunnel. As soon as the design and engineering have started, there is a further rapid augmentation of costs. Next large slices are needed for tooling, the production of prototypes and the production of test hardware. In the top year, 1966, 70 millions of guilders were spent. The top year of the wind tunnel testing was 1964, with 3 millions needed for that purpose alone. The picture once more shows the order in which the various parts of the work proceed and interchange.

As mentioned earlier, manufacturing parts is started as soon as the first drawings are ready. At the same time the design and manufacturing of tools is started, a part of the work requiring relatively large sums of money. As soon as there are sufficient tools, the building of prototypes is started. The figure shows how much money is involved in this work.

When a prototype is ready, test-flying is started immediately. It required in the first year some two millions, and in the top test flying year about six. There is a remarkable souce of costs in the documentation which has to be developed and which has in many programs given rise to quite some difficulties. The manufacturing of documentation is a millions of guilders business. It is always coming rather late because it is impossible to begin writing handbooks before the whole design has been sufficiently fixed. And then they must be completed in a hurry for use by the early customers. We delivered the first airplane early in 1969. Clearly, the first customer had to wait quite some time for his books. During this time he had to live with provisional information. The documentation forms a nearly continuous stream of work throughout the life of the airplane. Once you start developing variants of the airplane, development funds needed (per year) will show up new peaks. What is shown in fig. 5 is partly still expected cost, for the time scale extends into the future.

I would hope that this will give at least an idea of the organization of the development of an airplane. It should be obvious that it is very difficult to arrive at decisions initiating new aircraft programs. Therefore market analysis and marketing contemplations frequently form a very large part of the preparatory work. In the case of the F 27, however, we have solved this problem in a relatively simple way.

When we started with the airplane we wanted to make a short-haul airplane, an airplane for the short distances, using the most advanced propulsion formula available at that time, the turbo-propeller. This leaves open the size of the airplane. To determine this it is for instance possible to try to find out how many airplanes the world needs in any size category and to select the size maximizing the expected demand. This would seem to justify hope for a largest possible market. In 1953, the beginning of the F 27 program, the answer would have been that the airplane should be able to carry around 90 passengers. Ninety passengers is the size of the DC 9.

Unfortunately every manufacturer in fact makes the same sum and arrives at a very similar answer, around 90 passengers. So anyone acting correspondingly must count on many competitors. This tends to destroy his high expectations. So, with the F 27 we decided to use a totally different approach to the size problem. We set ourselves to make the smallest possible airplane which could be expected to remain sufficiently economical - in terms of cost per seat-mile - for regular airline use. We concentrated on finding out how small we could go with the airplane without penalizing too much this decisive type of economy. We arrived at the conclusion that we should make a 40 passenger airplane.

Now, I can of course after all say that we were very right, for we have sold 600 F 27's. an absolute top for European civil airplanes. This shows that the method worked extremely nicely.

I have a feeling that through this consideration, through this method and through this approach the marketing preparation became exceptional. It might well be impossible to transfer this method to other products.

With respect to the innovation aspect and with respect to research and development, I would say that the innovation in an airplane is not in the separate parts and properties of the airplane, in the materials, in the design, but in the new combination of all fac-

tors. In broad terms, you might say - perhaps with a few exceptions - that all airplanes are rather conventional. Every experienced aircraft manufacturer can design a new airplane and the novelty of the design is in achieving certain new specifications, in combining all the methods, all the knowledge, and all the experience available in such a way that a product is obtained which excells by some valuable property or combination of properties - economy, or speed, or passenger comfort say. Any airplane will in addition probably show up certain new detail elements.
I could e.g. mention the brake flaps at the end of the fuselage of the F 28 which is a very adequate arrangement used in this form for the first time. But if we had not equipped the F 28 with these brakes, we would have used a more conventional type of airbrake and it is of course not justified to say that we would then have sold less airplanes as we did up to this moment. So, this element of innovation remains of limited significance in the assessment of the value of the whole project.
With respect to research and development I will finish with one remark:
The amount of research which the aircraft industry cannot leave out to do is relatively very small. The process is typically a large development process. The research can be reduced so strongly, because once it is known that a certain new principle, or method, or material works, it generally becomes fairly easy to use it, if so desired. Now, someone in fact has to find out what novelty is feasible but there is so much free exchange of information that such information is very frequently to a sufficient degree available. Not in detail, but this can frequently be filled in without too much trouble and anyhow at relatively low risk.
This situation once more puts more emphasis on development than on research.

Innovation: A question of Creation versus Control?

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Professor Freeman has said that failure can be instructive. I will take as my subject the story of a company which lasted for no more than 6 years from the cradle to the grave. It was born in 1965 and became insolvent and passed into the hands of the receiver in October 1971. This company, Britten-Norman Limited, was exceptional because it was owned and managed by only two people, John Britten and Desmond Norman, and hence it was not too difficult to trace the key decisions which conditioned the rise and fall of the organisation. The full study can be obtained from the publishers, the International Institute for the Management of Technology in Milan. [1]

Britten-Norman Limited manufactured the Islander. It is an aeroplane originally designed and produced in the Isle of Wight which is an island situated off the Southern coast of England. The plane is twin-engined, has ten seats and a cruising speed of 160-170 m.p.h. There are about 380 currently in service around the world (Figure 1).

The second Figure shows the military version. All Islanders are designed to take off in less than 15 times the fuselage length, on runways which could be grass or sand. As you can observe from Figure 3 this is not a sophisticated plane. It is unpressurised, has a fixed undercarriage, uses mechanical control linkages, and reflects the basic philosophy which lies behind all Britten Norman engineering.

Simplicity is the keynote, and the Islander is designed for do-it-yourself maintenance and simple repairs in the field, and is corrosion-proofed for an expected flying life of 20 years. An innovation has been defined as 'The technical, industrial and commercial steps which lead to the marketing of new manufactured products and to the commercial use of new technical processes and equipment' [2]. While the new technology involved is small, the Islander concept itself represented an innovation.

The Trislander, shown in Figures 4 and 5, looks similar to the Islander but there are two major differences. First, the fuselage has been stretched to accommodate 18 people. Second, we note that a third propellor engine has been mounted in an unusual position, on the tail assembly. The prototype version of the Trislander, which incorporates 90% of the components used in the original Islander, was built and flown for about £16,000.

The Islander and the Trislander planes are not technically advanced, despite the undoubted technical ability of John Britten and Desmond Norman, who both trained as aeronautical engineers. They designed and built their first plane in 1949 - and then discovered that they could not sell it. They next established a highly profitable crop-spraying business, based on a superior atomising device which changed the economics of the spraying industry. Thet transported bananas for Elders & Fyffes and designed and built an early hovercraft in 1958 to avoid damaging the fruit. A derivative of this craft, the CC7, is still in production having been sold to the British Hovercraft Corporation after Britten-Norman Limited failed.

The Islander is essentially a tough and reliable working plane designed for simplicity and ease of maintenance. Their own crop-spraying activities had demonstrated that there was a real requirement for an economy-minded light plane in the short-haul market and they understood the user needs because they themselves were part of the user market. The Islander could be used for spraying; it was also popular with air-taxi operators because it had four more revenue-producing seats than the nearest rival. As you could expect in a design-dominated company, they later made a single-engined two-seater prototype which extended the basic Islander philosophy to the weekend and pleasure flying market. It was subsequently found through external market research that they could expect little demand from this market, and so this prototype was never produced in volume.

The workforce was relatively small (never more than 200) and came from a fairly close-knit community. They were intensely loyal, even after the company had failed, and despite the pressure imposed by creating ostensibly unreasonable deadlines on the design and development teams.

Why did they fail? They did not link the marketing and production activities of the business. They began making planes in late 1967 at the rate of one per week. By December 1967 there was an 18 month backlog of orders, and in early 1968 they decided to contract out all their production to the British Hovercraft Corporation and to Technoimport of Rumania, and to retain their own plant for final assembly operations. Despite this, less than one plane per week was being produced until mid 1969, when the depression in world aviation started to be felt. As demand slowed, and buying a plane is an eminently postponable decision, Britten-Norman was trapped between the declining market on the one hand and their planes being produced in volume under the terms of a fixed contract on the other.

The second important reason for their failure was due to the nature of the management control system. The two owners of the company were true ideas men with strong personalities. John is a free thinker, always scribbling his thoughts down; Desmond is almost 6'6" in height and a total extrovert. No one could stand up to this pair. They found financial control dull, and so it tended to lapse.

On August 31st, 1972 Britten-Norman was disposed of by the receiver for a price of £4.1m. It was purchased by Fairey Limited, an engineering company having annual sales of £19m., and a long association with the aviation industry. John & Desmond are now directors of Fairey Britten-Norman Limited and John is managing director of both the factory in the Isle of Wight, and of the Fairey plant in Gosselies in Belgium.

Finally, let me present their current innovation (Figure 6).

The new plane looks like the Trislander. It is planned to carry 100 people at about 230 miles per hour, and the family resemblance is clearly visible. It is a continuation of their basic philosophy, and is designed to be reliable, robust and very simple to operate away from maintenance bases under any conditions world-wide. For instance, it will use the widely available Rolls Royce Dane engine, of which 6,300 are already in service. It will cost about £10m. to place in production, and it may well be a joint venture with an existing company. Independent market research shows that it should sell - and the fact of calling for such a survey prior to prototype production is a significant step for John & Desmond. There is now a financial director to share control, and the company will use its own production facilities.

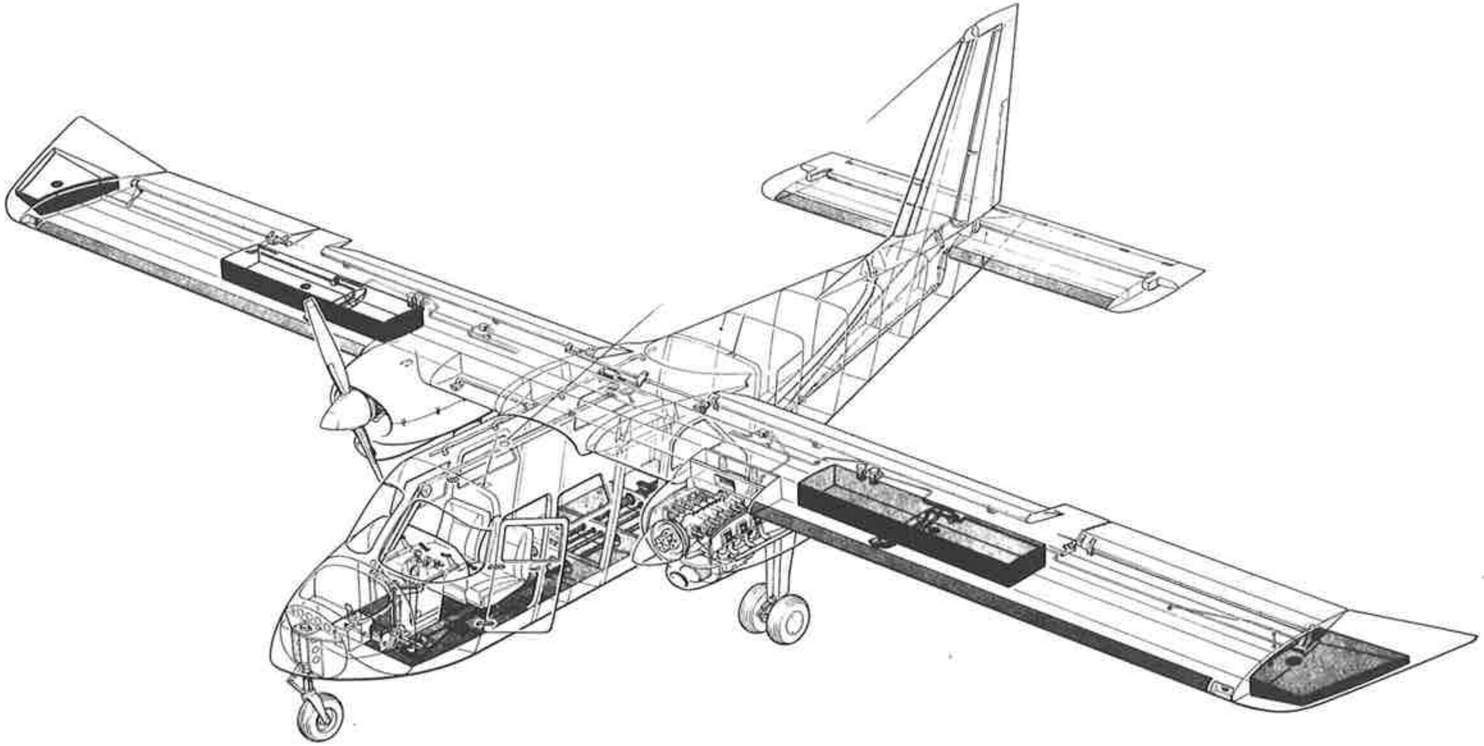
In conclusion, they are still very much creative people, and there is now seasoned management available to control the realisation of their many and fast-flowing innovative ideas.

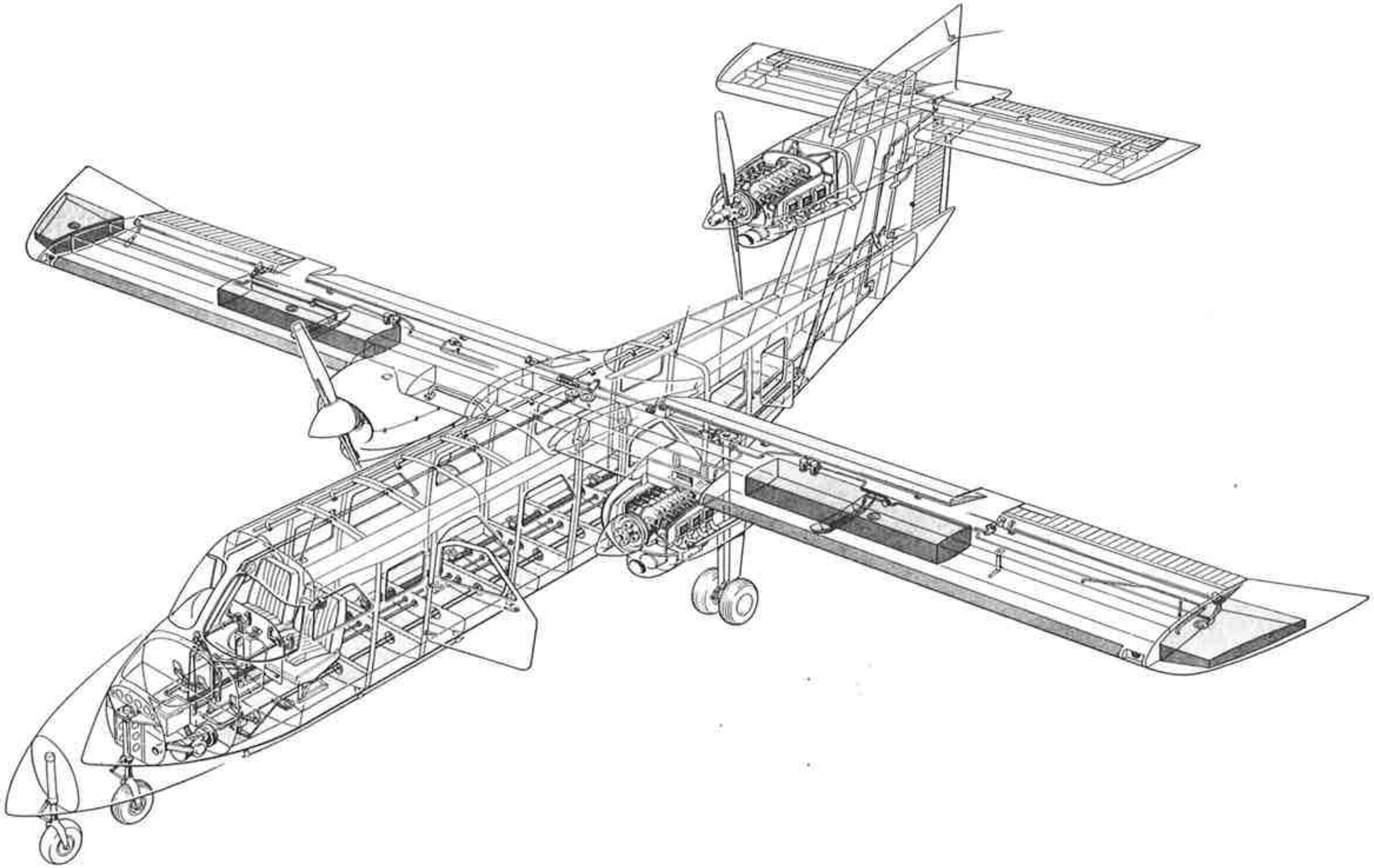
Refs: 1. 'The Islander; problems of the innovational entrepreneur' - David G. Lethbridge, International Institute for Management of Technology, Milan 1972.

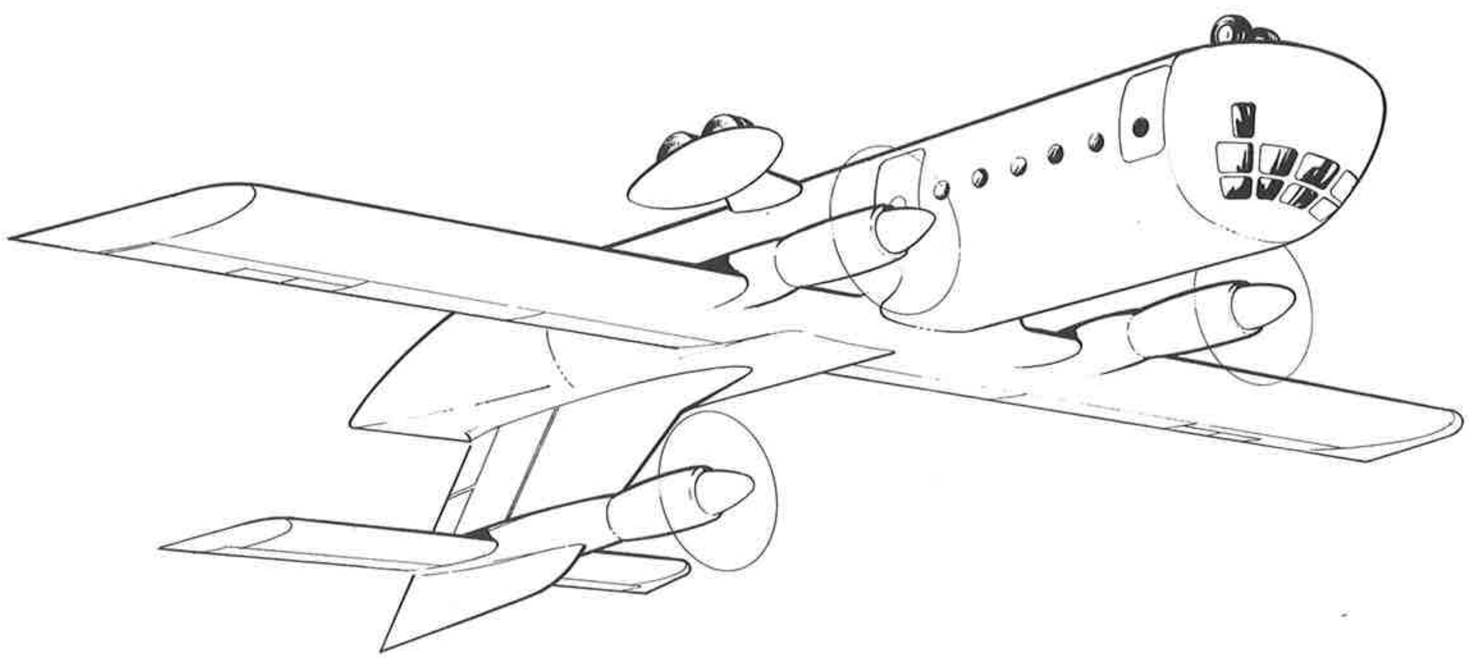
2. 'Technical Innovation in Britain' - Central Advisory Council on Science & Technology - Her Majesties Stationery Office, London, 1968.


G-AYK


G-AY







Development of the Variomatic

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The automatic transmission in question, the Variomatic, is suitable for private cars and it was developed by Van Doorne's Motor Works for the company's own 4-seater car.
Cars equipped with this automatic transmission first appeared on the road in 1958. Although many people were sceptical about the V-belt drive at the start, the soundness of the design has since been proved. It has now become fully accepted.
At the start it was used in the Daffodil, which was equipped with an engine developing 25 BHP (30 SAE HP). Now it is also in the DAF 66 with an engine of 47 BHP (55 SAE).

In comparison with a car having a conventional 4-speed gearbox and the same engine output, the following advantages can be seen.

- Better acceleration from 0 - 50 km/hr than with a conventional gearbox. This acceleration is particularly noticeable in town traffic. In busy town traffic brisk acceleration is essential for keeping the traffic on the move. Acceleration is a stepless smooth-flowing process. Since the driver does not have to change gear, he can keep both hands on the steering wheel and the car can be guided rapidly through busy town traffic.

- Increased reliability, as overrevving of the engine is impossible and incorrect operation is virtually ruled out (fool-proof). In normal conditions, except when driving downhill at a speed above 140 km/hr, engine revs never exceed 4,800 rpm. Gear-changing is limited to engaging forward or reverse drive.

- Safer driving, especially in mountainous regions, on account of the simpler controls; since there is no changing down the driver does not have to take his hands from the steering wheel and can devote all his attention to the road and the other traffic. Driving-off on a gradient, which many drivers find difficult, is child's play with the Variomatic and the centrifugal clutch. There is no doubt that in mountainous regions and in town traffic where it would otherwise be necessary to change gear continuously, it is considerably less tiring.

Operation

Fig. 1 shows the stepless automatic gear.

Fig. 2 shows how it is installed in a car.

Fig. 3 gives a section through the Variomatic transmission. When the centrifugal clutch is engaged the torque is transmitted by the propellor shaft to the power divider, which divides the torque equally. The pitch circle of the belts can vary, sothat a transmission range of 4 is achieved. The opening between the two pulley halves can become greater or lesser.

In the power divider the pinion bevel gear meshes with two side bevel gears. A dog clutch couples the pinion, which is integral with the propellor shaft, to one of these side gears, thus enabling forward or reverse drive to be engaged. The power divider and the reduction gear cases are rubbermounted to absorb vibration and reduce the noise level.

Pre-load on each belt is obtained by means of a disc spring and a coil spring on the sliding secondary pulley half. The disc spring also couples the sliding pulley to the reduction-gear input shaft.

Each sliding primary pulley half contains two centrifugal weights attached to the power divider output shaft. These weights force the sliding half, by means of cams, towards the fixed one. Furthermore, each contains a relatively weak disc spring which assists the centrifugal force in the lower speed range and also couples the sliding primary pulley to the power divider output shaft.

Moreover, each of the sliding primary pulley halves acts as a vacuum cylinder and is divided into two chambers by a diaphragm. The two chambers of each pulley half are subjected to vacuum independently of each other by means of two hoses mounted on the off-side of the sliding primary pulley. The total axial thrust on this sliding pulley half is able to alter the position of the belt on the pulleys. This axial thrust is dependent upon engine speed, pulley opening and the degree of vacuum in the cylinders.
The combination of these factors provide the results shown in the variogram (fig. 4).

Vehicle speed is indicated horizontally and engine speed vertically. The engine speed curve as function of the vehicle speed must be between the low and the high line. For maximum acceleration and climbability it is desirable for the full throttle curve to follow the low line as closely as possible to 4,000 rpm and then the horizontal 4,000 rpm line until the maximum speed is attained.
For economic and quiet driving it is desirable for the road-load curve to follow the 2,000 rpm line as closely as possible. This we call the overdrive-effect.

The position of the belts for the full throttle curve is quite different from that for the road-load curve. This difference is due to torque sensitivity of the belt and to the influence of the vacuum. A vacuum valve is connected to the accelerator pedal via a micro switch. The vacuum present in the engine inlet manifold below the butterfly valve (the so-called engine vacuum) van be admitted via this vacuum valve to the outer chambers of the vacuum cylinders on the sliding primary pulley halves. At another accelerator pedal position air instead of vacuum can be admitted via the same vacuum valve.

The engine braking valve incorporated in the plastic housing allows the inner chambers of the vacuum cylinders to be connected to vacuum. This occurs when the transmission low ratio hold switch is pushed in by the driver. If the accelerator pedal is released, this valve gives a striking change-down effect, resulting in powerful engine braking, which is very useful on steep gradients. The engine braking valve is also opened when the foot brake is applied. This is necessary to make the belt drive change down rapidly when braking. For the sake of completeness: on fig. 5 you can see the centrifugal clutch.

Now we come to the question why DAF made a Variomatic transmission unit and <u>how</u> we developed it.

At the time DAF brought out his first car in Holland the story was told that Mr. Hub van Doorne had used his own braces to test the variable V-belt principle and he was so impressed that he made the Variomatic.
To be serious I mention one of the real reasons.

To carve out a position among other well-known car makers Mr. Van Doorne, the founder of DAF, thought he needed a special item in the form of an innovation for an important part of the car.
The same policy as he adopted with regard to trailers, semi-trailers and military vehicles. For the innovation in the field of cars he choose the transmission, which he felt was most necessary because a manually operated transmission is a poor link between

engine and driven wheels.

He considered a stepless transmission to be the ideal solution. Among the stepless transmissions, as, for instance hydrostatic, hydrodynamic and friction drives the V-belt variator gives the best overall efficiency and the lowest production cost.
A disadvantage could be the dimensions. But we thought it could be incorporated in the smallish car we intended to produce.

The development of the Variomatic was in fact the result of the wish and drive of one single man, who knew what he wanted.

The problems in connection with the development of the Variomatic, which was done inside the company, were:

1. a high power belt of small dimensions.

2. a degressive force on the secondary pulley, which was achieved finally by a disc spring.

3. the movement of the sliding pulley halves without too much friction under torque.

4. an automatic clutch.

5. regulation of the belt position for all road conditions.

These and more problems were solved by an enthusiastic team of young people who had little experience in car designing. With sufficient inspiration but much more transpiration.

At the end of this lecture I will also try to express my opinion on the organisational and personal aspects, which are benificial to successful technological innovation. I will summarize this in a few rules.

1. At the top of the firm you need a man, who is innovation-minded.

2. The climate in the firm has to be ambitious and modern and not burocratical. All employees must have pleasure in their work.

3. Communications in a technical department have to be easy through the levels, really democratic.

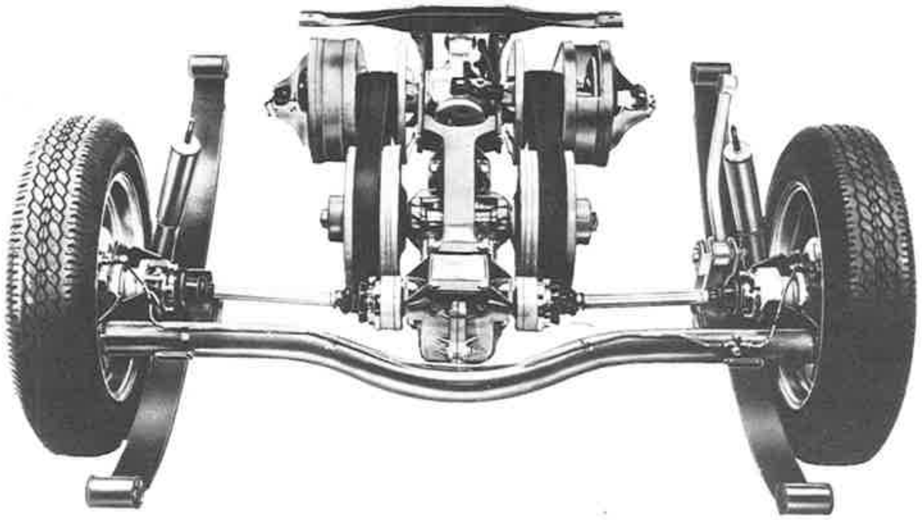
4. A new idea should be worked out by a small team which works separately in some cases, also geographically.
   In this team you need on the one hand inventive men and on the other critical men and a man with broad knowledge of designs related to the subject.

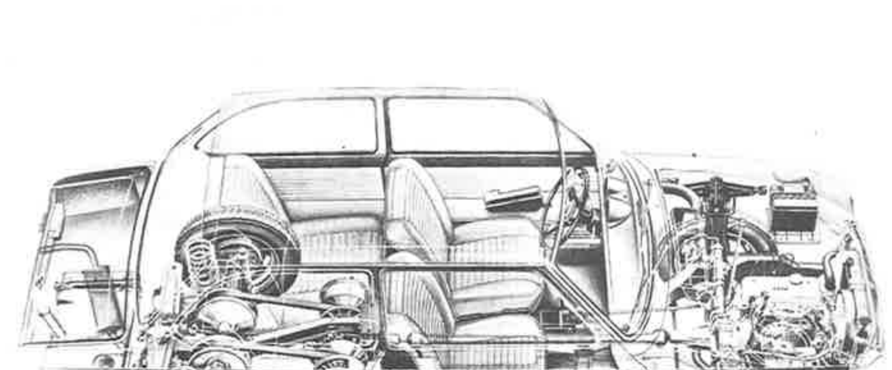
5. There is always a more simple, cheaper and better solution than you already have.

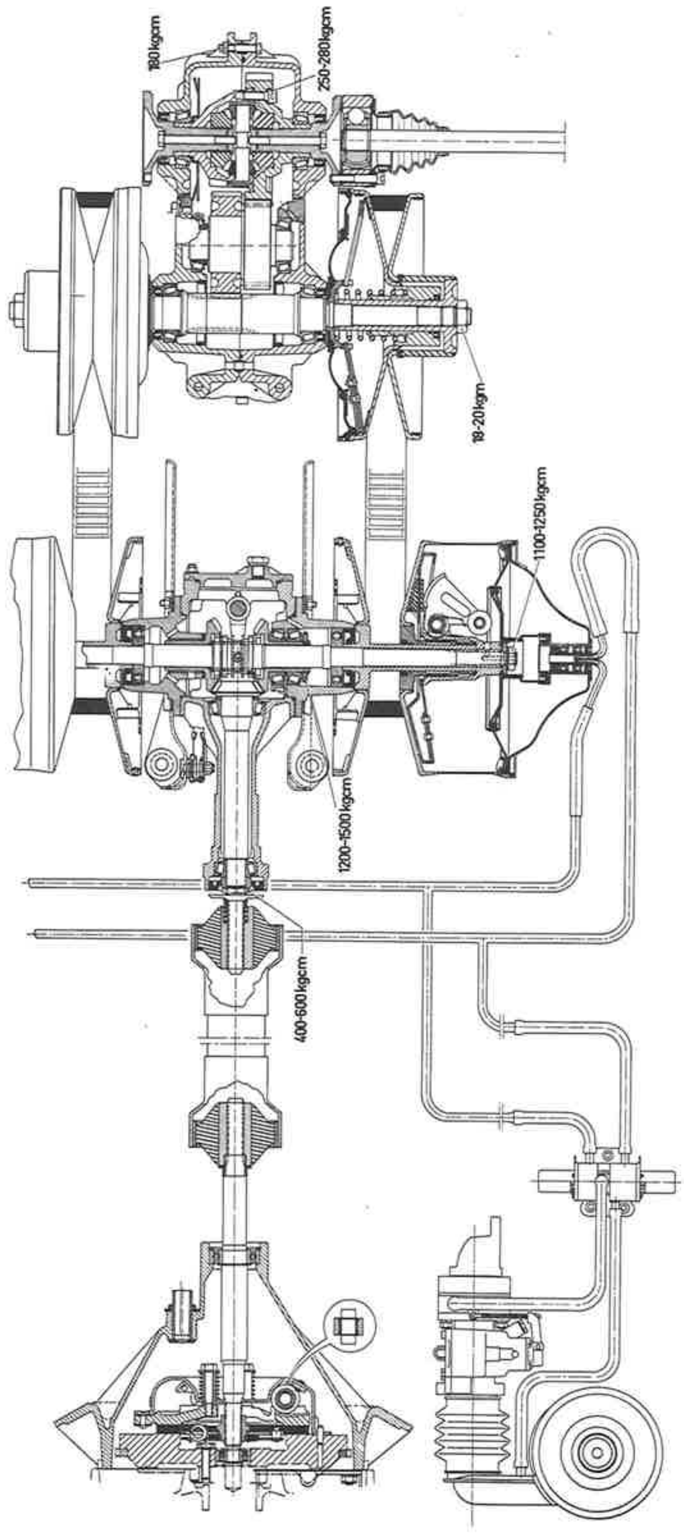
6. Inventivity is not promoted by pressure, more by enthusiastic indoctrination.

7. You need a good workshop with experienced and fast-working people.

8. The managers should take the decisions which belong to their field, the technical decisions should be taken by the specialists.



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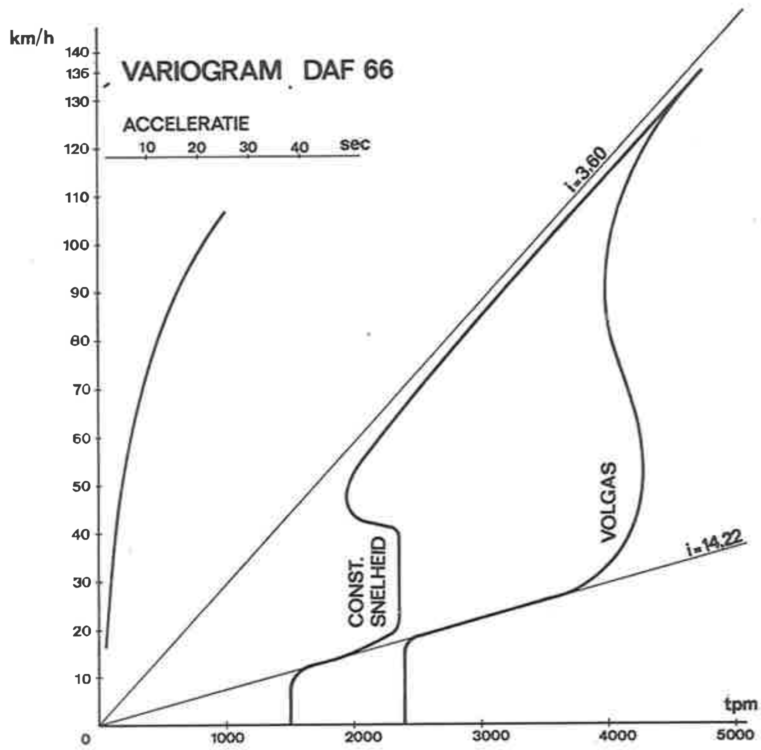

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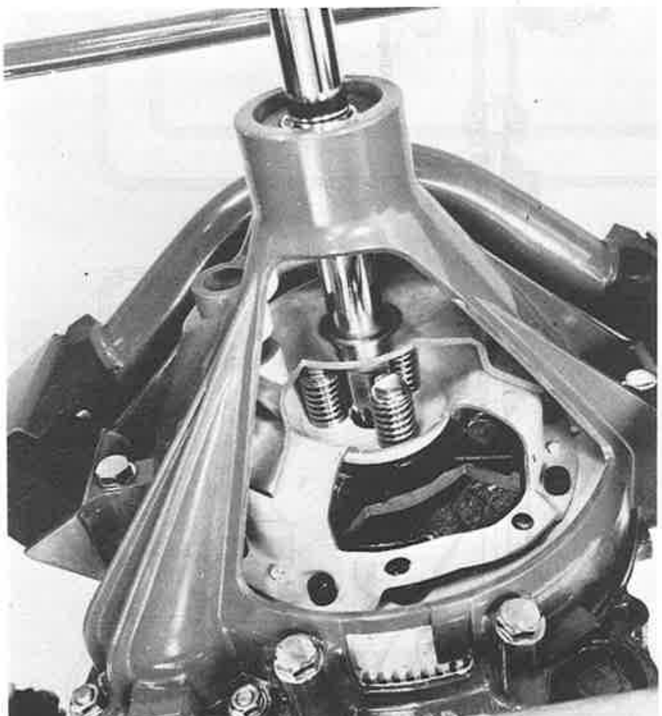

The shuttleless weaving machine

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Te Strake B.V.
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For a very long time the insertion of the weft in weaving was done by means of a shuttle. Only after the end of the First World War unconventional ways of producing cloth were shown to be attractive alternatives. The manufacturers of conventional machines reacted by introducing improvements in their machines that gave a considerable reduction in labour costs and an increase in production. The conventional machines are still on the market and up till now the manufacturers have succeeded to parry the competition of the new systems. But the development of alternative machines has accelerated in the last ten years. The pace-setter is the Sulzer system, which opened the eyes of the textile industry to the possibilities of unconventional weaving. It is estimated that in 1973 about 30 per cent. of all sales will be in unconventional machines.
The big competitor of weaving is knitting. On a world-wide basis about 13 per cent. of all cloth was knitted, and it is expected that the percentage will rise to about 16 per cent. in 1975. Considering the economics of both processes and the structure of the fabrics, we do not expect that knitting will oust weaving.
In general, the different types of weaving machines differ in the insertion system only. A rather new development are the multi-face systems with a number of small shuttles operating simultanuously.
We did some research in unconventional weaving systems too, and it led us to the conclusion that yarn speeds of sixty to eighty meters a second - and maybe even higher still - might be possible. This gives an insertion capacity of 1800 to 2400 metres a minute, depending on the duty cycle. A second conclusion was that most existing systems would not be able to reach speeds like these even after further improvements. So the decision to start the design and development of a new type of weaving machine was based on sound facts and on the insight that the market for weaving machines was open to changes. We designed a number of insertion systems that promised to give us the insertion speeds we wanted. In the end, all except one were rejected and we went on with the air-jet system. In this system the yarn is taken of the packages continuously and passes the main injector which introduces the yarn into the machine. Multiple air-jets then take over, they act upon the yarn and push it across the machine. It will be clear that with this system any width can be covered.
Before discussing some of the problems we encountered in developing this idea, it is necessary to point out that our firm is a machine factory with an annual turn over of five million guilders. Part of our production is in textile machinery.
From 1960 up to 1970 the development of the shuttleless weaving machine was financed by a development grant from the Ministry of Economic Affairs. The first prototype was shown on the ITMA fair at Basel in 1967 and improved prototypes were shown in Paris at the ITMA fair of 1971. In 1970 and 1971 market research by external consultants indicated that our weaving machine might conquer between 2 and 3 per cent. of the market in a relatively short period, which would mean a turn-over of more than *f* 100 million. So in 1970 it was decided to build an assembly plant for the shuttleless machines. After the first series of five prototypes, that were exhibited in Paris, we started the production and the sales affort for a series of 50 machines.
Early in 1972 we were confronted with a number of unexpected facts. We always had thought that demonstrations in our own weaving shed would convince potential customers of the possibilities and the capacities of our machine. This philosophy turned out to be wholly erronous. We discovered that we could not sell a machine before the customer had tested it for several month's and that good test results were but a part of the motivation a customer needed before he decided to buy. In consequence we had to set aside twenty new machines for customer trials in Europe and the U.S.A. We also had to discover what our potential customers expected of us, a newcomer in the market.

After analysing our experiences and results, we had to decide that we better could postpone our entry into the market until 1974. Of course this meant a considerable addition to the financial strains. Early in 1972 we started to look for an experienced builder of weaving machines who would be interested in a merger and who could assist us with engineering, production, applications, marketing and sales. We have found a partner in a well-known Swiss firm and it is expected that the negotiations will be finalized in March 1973.

Short description of our innovation process

The conception of the idea is the most important part of the whole innovation process. Research and development resulted in a functional concept of the new weaving machine. A number of the R & D problems were beyond our own specialisms and we sought outside help for their solution. It turned out, however, that some of the problems were very specialized and asked for much support from our side, as there was almost no litterature or general knowledge extant.

System engineering

This intermediate step between development and production nearly completely failed. The know-how necessary for succesful system engineering was not available in sufficient amounts. A very important factor was lack of time. We were financed by a development grant and due to our insufficient grasp of the whole innovation process, we were forced to do too much in too short a time. The engineering activities aimed at achieving quick results by a method of trial and error.

Production development

Due to the structure of our firm, we could only make a certain number of components of the machines ourselves. Therefore, it was decided at an early stage not to manufacture the machines, but only to assemble them. In addition it was thought that this would give us great flexibility in the choice of manufacturing processes. Here too, we ran into unsuspected difficulties, caused by a certain lack of structure of the part of the industry we had to approach. There was spare capacity, but it was not concentrated. We had to find a sufficient number of suppliers, without compromising quality, quantity and costs. The problem of production development had two sides: the selection of manufacturing processes and the choice of suppliers.

Market research

Up till 1971 we followed the method of inside out instead of outside in. The ideas of the designer and management determined our efforts in research and development. Now we know that marketing is a leading input factor in these activities.

Finance

We can see now that in 1970 our weaving machine was only in the stage of a functional prototype. We thought, however, that we were already in the next stage of commercialization and attracted credit on that basis.

Conclusion

Considering the background of the speakers who presented a case history here, I am again confirmed in my impression that our story is an exception in Dutch industry. For a small company it is well-nigh impossible to tackle a problem as big as this. Maybe I am stressing smallnes too much, but our experience has convinced us that the innovation to be developed must be related to and should be an extension of the activities the firm is already engaged in. We learned that it is nearly impossible to compensate for lack of inside knowledge and therefore the innovation to be developed should be related to the normal activities of the company. We are sure that we now will find compensation for our previous imperfections in the close co-operation with our Swiss partner.

A special two layer welding technique resulting in refining of the weld heat affected zone

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In the preceding case studies we have heard about innovations as being new products. In the case I intend to present the innovation consists of a new production method. Another difference is that the former innovations were meant for broadening the production or selling basis of a company or for replacing older products with a decreasing sold volume. The present case describes a situation that arose after the discovery of material defects. Defects of the kind that were discovered had never been noticed before. Safety arguments made it advisable to try to avoid the formation of the defects. Different stages in the process of developing new techniques that fulfill this aim will be mentioned separately.

1. Study and definition of the problem

The defects consisted of small cracks in a zone next to a weld. This zone is heated to a very high temperature during welding and obtains a coarse crystalline structure. The defects are not present immediately after welding, but only develop after some time in a limited temperature interval during a so-called stress relieving heat treatment. The defects are caused by local stresses related with the welding process and shrinkage after welding.

2. Possible actions

The possible actions to avoid defect formation that were seen were:

a. the choice of a metal showing no susceptibility to crack formation, even in a coarse crystalline form
b. the avoidance of a coarse crystalline zone next to the weld
c. the reduction of stresses

3. Discussion of possible actions

The change or material was not seen as the most promising action because, first, R.D.M. is not a steel producer and, more important, a change in material composition has many consequences because of code requirements and technical conditions as, for instance, neutron embrittlement during service in a nuclear reactor.

The reduction of stresses was not seen either as a promising action. First, because the stresses evidently have a very local character. This makes a determination of the stress level very difficult and consequently hinders a systematic approach. You can't measure what you have reached. The second argument is that the susceptibility of the material for crack formation remains present.

The choice that was made was to try to get rid of the coarse crystalline zone. Now, in welding the temperatures are so high that allways a coarse zone will come about. So the only possibility was to reheat the steel after welding to such a temperature that recrystallization and hence grain refining takes place. This reheating should be performed at a speed sufficiently high to pass the temperature range where crack formation can take place before this actually happens. For this rapid reheating three possibilities were seen, i.e. a traveling arc discharge, a middle frequency induction heating, and, with a proper choice of the parameters, the welding of a second layer on top of the first one.

4. Final choice of possible actions

In the choice between the remaining possibilities, a very important argument was that the people that had to perform the job in practice were experienced welders. So, in order to avoid a time consuming instruction period and installation of new equipment, and also in order to avoid the resistance of each production department against the introduction of new techniques, the two layer welding technique was chosen.

5. Development of production method

After the choice was made, the correct production technique had to be selected. This led to a large number of weld tests.

6. Acceptance by inspection agencies

After the internal acceptance of the method had taken place, the external acceptance was obtained by welding and testing a number of so called procedure qualification tests in the presence of independent and authorized inspectors.

PANEL DISCUSSION

PANEL: Dr. W.G. Evans, Chairman
Dr. H.J. Greidanus
Dr. D. Lethbridge
Ir. H. Ludoph
Dr.Ir. J.P.F. Mulder
Ir. G.J. Vermeulen

(Evans) At this stage I am reminded of three lines that appeared on a wall in Cambridge a few years ago: "To be is to do", Jean Paul Sartre; "To do is to be", John Stuart Mill; "Dobeedobeedo", Frank Sinatra. I think, this sums up this morning, there were very few variables and many combinations. You have heard five different case studies, but I do not think that the differences have been quite as marked as we'd liked to believe, as they all came back to the same thing: Experience, won the hard way. The Fokker cases were very large and in the Islander success and failure intermingled with an element of survival still evident. The shuttleless weaving loom encountered problems in the second half of the innovative process and in the DAF case all technical and commercial problems were overcome. The welding case showed the importance of finding quick solutions for unforeseen difficulties that suddenly crop up.
Now, you will be itching to attack the panel, and we are ready to repulse all attackers. So, without any further introduction, may I open the meeting for discussion?

Question

I have a question for Dr. Greidanus. The development of an airplane ties up an enormous amount of money and I take it for granted that, before you decided to start the project, you did a number of analyses, such as market analyses, financial analyses and so on. I am greatly interested in the kind of methods you have used.

(Greidanus) I am sorry, but I don't see exactly what you are aiming at. Can you be somewhat more specific?

What I meant is this. The development of a new airplane involves tremendous amounts of money, you have to invest very large sums before the first prototype is ready to fly for the first time. Before you decide to develop a new plane, you must have a clear idea of the risks you take and the possibilities of reaching the break-even point or going beyond that. I think that this calls for very careful analyses of all factors that bear upon the share of the market you hope to reach, your financial resources, the risks you are running and so on. It seems to me that the evaluation will involve a number of techniques of analyses, and my question is: What did you do and what methods did you use?

Answer

(Greidanus) There is a marketing and an engineering side to your question. When you start to think about the development of a new plane, the first thing you do is to evaluate the state of the market. You make a careful analysis of the world traffic network, the fleets, the traffic densities on the various lines and so on. This is a must, every aircraft manufacturer has to do it. In our case the evaluation indicated that it might be worthwhile to aim at the lower end of the market and to develop a small plane, because there are many airlines in the world that serve regions where traffic is not very dense and that don't have the financial resources to buy large planes in any case. Then we determined the smallest possible size that would make the new plane still economically attractive to our future customers. This was not strictly a marketing job, our engineers had a big say in it, and of course we had to look at seat-mile costs, total operating costs and all that. Then we could start to design a plane that would meet the speci-

fications we had laid down. Of course I have left out a large number of details and intermediate steps, but the basic ideas are rather simple and logical: You start to pinpoint a need and then you try to satisfy that need.
The part of your question about methods and techniques is not easy to answer. Most aircraft manufacturers use fairly standard methods, the evaluation of the traffic network and the existing fleets of airlines certainly is a standard procedure. This must not be taken to mean that we are afraid to use new methods and techniques as they become available, we have done so in the past. However, the development of a new plane involves enormous amounts of money, so we must be sure that our methods of evaluation give absolutely dependable results. You did say, I think, also something about the break-even point. If you wanted to suggest that the prediction of the break-even point is very difficult, I fully agree with you. In our case we originally thought that we would have to build 70 planes to earn back our investments, actually we had to produce nearly twice that number - 135 - before breaking even. It did not matter very much, as in all we sold 400 planes and another 200 were build under licence in the United States. Does that answer your question? Thank you.

Question

What is the role of pressure in innovation? In his presentation Mr. Ludoph remarked that he preferred not to work under pressure, Dr. Mulder mentioned that there was extreme pressure when developing the welding technique. But what is the influence of lack of time or money in general?

Answer

(Lethbridge) In the case of the Brittain and Norman organization, pressure was almost paramount. They believed in having dead-lines that were impossible to meet and they got the whole factory behind them. There was an incredible esprit de corps, even after the firm had passed into the hands of the receiver and there had been reductions of staff, and the future did not look very bright for those who remained. Brittain and Norman was a pressure organization, but the result was a climate that was certainly creative.

(Evans) Professor Shapero has a question.

(Shapero) Well, it is not a question, it is an addition. Dead-lines probably are one of the most effective mechanisms for getting anything done, and there is not a man in this room who has not lived and died around a dead-line. I think it is one of the most overlooked measures to get something completed. If you put the dead-line further of, it will be met around that date, and there is a Parkinsonian law that the effort and the output will adjust itself to fit any dead-line.

(Evans) As Dr. Johnson said: Execution sharpens the mind wonderfully.

(Ludoph) Perhaps my remarks on pressure in innovation have been somewhat misunderstood. I really meant to say that there is a difference between working out a new idea and the development of a new construction. In my experience pressure is no good in the stage of working out a new idea when you have to invent things to make the idea work. But you certainly need pressure in the stage of the development of the construction. That is the distinction I wanted to make when presenting the case of the Variomatic.

Question

Can the panel tell us something about the ratio between development costs as estimated in the budget and the actual development costs?

Answer

(Evans) We have here Professor Freeman and Dr. Robertson who have a lot of experience in analysing projects from that point of view, and I would like to ask them if they have any contribution to make.

Oh, no, I did not mean that, I only wanted to hear for the cases we have just heard.

(Lethbridge) In the case of the Islander, research and development costs were estimated at £ 380,000; when the plane received its certificate of airworthyness, actual expenditures had been £ 880,000.

(Greidanus) In the case of the F-28 development costs were estimated at ƒ 103 million and the actual costs were ƒ 145 million. But in this some work is included that was not foreseen in the original estimates and part of the overshoot was caused by inflation, so actually we succeeded in keeping tight control on our development costs.

Question

I have a question about huge projects like the development of an airplane. Undoubtly this requires a large number of innovative steps and I would like to ask Dr. Greidanus what he considers to be the most important innovative step.

Answer

(Greidanus) The question is a very difficult one actually, as the processes are so complex that there are bound to be many new things in a new plane. But most of the innovations will have originated elsewhere and only are used by the aircraft manufacturer. Engines are a good case in point, first we had explosion engines with propellers, after that turboprops, then the turbine proper and now high-pass ratio turbines. All innovations in this sequence originated with the engine industry and not with the aircraft manufacturers. Carbon fibres are a more recent example. They are not used yet in civil aircraft to my knowledge, but they will in the future. These fibres were invented for us by others not in the aircraft industry, and we know that they have quite interesting properties as a reinforcement for certain materials. We are actively interested in carbon fibres and we want to know what matrix materials are suitable and what properties the composite has, like tensile strength, fatigue strength and so on. But when we know all this, we might still decide to use known and well tried materials, for you have to do a lot of quite expensive testing to make sure that it is safe before you can introduce a new material into a plane. So the advantages of a new material have to be very obvious. I think that I cannot give a general answer to your question, perhaps a computer expert can do it better, as new advanced computers seem to bristle with decisive innovations. In our branch of industry the crucial step is market analysis; as I said before, you have to pinpoint a need and to produce a design that will meet that need. That is crucial, it decides your future succes or failure on the market. Does that answer your question? Thank you.

Question

Professor Shapero said: If you put your R & D people near a university, they will produce papers and if they are next to the sales department, they will invent products. Mr. Ludoph just told us that in a number of cases a certain distance between the laboratory and the factory floor is recommendable. Are there any general criteria you can apply when you have to decide where to house your R & D if there are boundary conditions as, for example, that you know that product engineering is an important part of your development effort?

Answer

(Evans) There is, I think, no general answer to this question, it all depends. If the university only teaches the humanities, you may get well written reports and papers full of historical allusions, and you may not want that. But can I ask the members of the panel for their comment?

(Mulder) In developing the new welding technique we were working under extreme time pressure. In the first stages we preferred to work with doors closed, but later on close contacts with the people on the factory floor were essential. So I agree with the chairman that it all depends and that each particular problem should be considered on its own merits.

(Ludoph) I fully concur with the conclusion of my colleague here, it all depends on the particular problem. When we were working on the first stages of the development of the new transmission, we did not want to be influenced too much by other departments, but later on good contact with other departments of our firm became rather important. Perhaps I may mention one curious result I observed. In a reorganization in our firm a design department was transferred to a sales department. But this resulted in the complete disappearance of the whole design department. I don't know why it happened, but motivation may have had something to do with it.

Comment

On hearing this discussion, I get very angry and despondent. What is this all about, talking about where we will put our R & D people, next to a university to produce papers or next to a sales department to produce products? Can I remind you that yesterday one of the most important factors in the innovative process which was mentioned, but not discussed, was the factor of people? What matters is what kind of people you have got, how you motivate them, how you inform them, the direction you point out to them and then the succes which you can gather. There have been tremendously succesful developments from guys with a spanner and a screwdriver and equally succesful developments from high-powered R & D departments. We seem to forget that the main springs of innovation do not necessarily lie within research and development, and I say this as a lifelong working scientist and researchman. It is an arrogance and a stupidity to believe that just because we have been trained in research we are the only people who can innovate. Innovation may arise anywhere in a company, it may arise on the shop floor or from a transport driver, it may even arise from the bloke who is cleaning the factory yard. A company which is innovation minded will have the mechanism, the awareness and the sixth sense to pick it up and take it further. That is where a R & D department which is deeply integrated within the company structure, can be of assistance. A previous speaker tried to get the panel to define the actual innovative step that they had undertaken and I thought that there was a great deal of confusion between the initiator, the jump over the barrier, and what subsequently followed because of the logic of the process. It is only the initiation that I would consider as true innovation.
I am from Pilkington, and we run a process, the 'float process', which makes very beautiful glass, and we licensed it all over the world. The initial, the creative step happened when Alistair Pilkington was washing up one evening, saw soap bubbles floating on water and asked himself: Why don't we do that with glass? It took a tremendous effort in physical and chemical engineering to make the idea work, but it was subsidiary to this basic, innovative idea. And may I remind you that Alistair Pilkington is not a scientist, but an engineer?
What I want to say is that succes comes from the way you motivate and inform your people and from the guts you display in following the discipline of succes; succes imposes its own discipline and its own troubles, and if you are unable to grasp succes you'd better not start.

(Evans) I thank the gentleman from the audience for his timely reminder that innovations are invented by people and that people should not be shoved around like things.

Question

Yesterday Professor Freeman remarked that the market mechanism does work very well in the capital goods market, but less well in the field of consumer goods. His point was, I think, that with capital goods producer and consumer both are professionals, but that with consumer goods the producer still is a professional and the consumer an amateur. Now we all heard Dr. Greidanus stress that in the design of a new airplane the crucial step is market analysis, whereas Mr. Ludoph in the presentation of his paper did not mention market analysis, but talked about the vision of one man, Mr. Van Doorne. Of course we all know that his vision and his ideas were very good ones, as his firm succeeded in entering the highly competitive consumer market of passenger cars with succes. So my question is whether DAF did do market analysis before introducing a passenger car containing the Variomatic. Or do you think that in a case like this an analysis of the preferences of the public is nearly impossible?

Answer

(Ludoph) Thank you for your kind words about the vision and the ideas of Mr. Van Doorne. But you did ask two questions that are rather difficult to answer. Considering everything, I think we must have had a good idea of the state of the market in passenger cars. After all, we were an existing firm, producing in a very competitive field and we were well used to market analysis. We are doing a lot of market research for passenger cars now, and we are taking the results very seriously. And I don't think that in consumer goods, market analysis is an impossibility. Before I came here I had the impression that it was somewhat easier in capital goods, but after the papers of yesterday and today I am not so sure anymore. However, I fully agree that market analysis in consumer goods is difficult and I have a good example. After the end of the Second World War the government decided that we had to industrialize. A number of different projects were studied and one was the production of passenger cars in Holland. The committee that investigated this question had in mind the same kind of car that was produced in other European countries, and the members of the committee concluded for very good reasons that such an industry would not be viable in our country. Mr. Van Doorne tackled the question from another point of view, and he came to the conclusion that the public wanted a not too expensive car with a not too expensive automatic transmission, and he invented one. If he then had toured the market asking who needed an automatic transmission with a V-belt, I would not like to visualize the kind of answers he might have got. There is a difference between market analysis and vision, and I agree with the remark of the gentleman from Pilkington that people and their ideas are extremely important.

Comment

(Evans) One thing I regret about this particular set of case studies, and that is that they have a marked mechanical bias. They have all been about things, whereas I understand that many of the audience com from the chemical industry. I wonder whether anybody in the audience would like to make a contribution on any differences, if they see them, between innovation in the chemical industry and the mechanical type of projects we have heard about this morning. Perhaps they would like to make the definite assertion that in fact the processes are exactly the same.

Question

I am from the chemical industry and I accept the challenge. I would like to introduce into the discussion the concept of the product life-cycle. The life-cycle is an essential characteristic of many products and in the chemical industry the impression is that life-cycles are shortening. Now we have had here a product with a very short life-cycle, and that was the welding innovation. It seems to have been used only because there were no cheaper or better methods available at short notice. But if we look at the Variomatic, we see that it has been on the market for more than fifteen years and that is considered a very good life span in the chemical industry. Now I'll take over the question of the chairman. Does the panel think that there are important differences between the chemical and the mechanical industries or are mechanical engineers less innovation minded than chemists?

Answer

(Ludoph) Not being a mechanical chemist, it is difficult for me to comment on this question. But I don't think that mechanical engineers are less innovation minded than chemists, it seems to me that age has something to do with it. The chemistry of synthetics is rather young and you can expect that chemists are innovating in that field at a tremendous pace, just to see what they can do. In mechanical engineering the situation is more mature, we have had our period of rapid innovation rather long ago. In that respect there are differences between the chemical and mechanical industries. If we look at the Variomatic and if we are quite honest, we have to say that it is not a new idea. V-belt variomatics were used before Mr. Van Doorne thought of using them in a passenger car. And a time span of more than fifteen years is not exceptional. Just take the normal gear box, it has been in production for more than eighty years now. Of course, there have been improvements, like the automatic meshing of gears and there have been new materials. But the gear box was used before the turn of the century.

(Vermeulen) I would like to add that innovation in the mechanical field cannot be considered on its own only, there is interaction with other fields. We have seen that with textile machinery. For tens of years manufacturers of textile machinery had to take into account the properties of yarns of natural fibres, like wool and cotton. But now the chemical industry is inventing new yarns with a great range of properties every week so to speak, and partly as a result of this, innovation in textile machinery has started again. You have to take in account restrictions like these before you can say in all fairness that a particular branch of industry is not innovation minded.

Question

When we are discussing innovation, should not we have a good look at what it is doing to our non-renewable resources, like minerals?

Answer

(Evans) This is a very difficult question, it is the question of the role of the consumer society. Perhaps someone in the audience can make a contribution?

Well, I don't know how we should tackle the problem of non-renewable resources. But one of the results of innovation is a stream of new products and gadgets, and this is phenomenon that should be studied very seriously. One of the causes is, I think, that we, as bosses, expect our designers to be creative. So they are creative, they come up with many new ideas and some look good and are turned into a product.

(Evans) Thank you for your contribution. I think that it is a matter of practical reality that any organization geared to production simply does not want too much creativity. I have an interesting anecdote about that, which I heard when I was investigating the hovercraft. Cockerell invented the hovercraft and then built the SRN-1 - a one man craft - the SRN-2 that could carry about 10, and then the SRN-3 that really could do some business. One day the SRN-3 was demonstrated to a group of military men and some of them got rather exited about it and wanted to buy one. Then Cockerell intervened and said: "Don't do that, for we are busy on the SRN-4 and that is the craft that will do everything you may wish." The production boys could have strangled him on the spot, because the customer listened to him. Well, the SRN-4 was coming, but it took another four years before they had the first prototype. So let us not kid ourselves, innovation is very good, but we don't want too much of it.

By now it is time to make a short summary and to look at some of the lessons we learned. The first thing we discussed was analysis and prediction and we saw from the Fokker case that prediction is very difficult. They were nearly one hundred per cent. too low in their estimate of the break-even point, they thought it would lie at 70 planes, it turned out to lie at 135, but their market analysis had been good and they succeeded in selling 600. There was the role of pressure and deadlines in innovation, and stimulating people to come up with the right answer. We spent but little time on the question of finance, which is just as well because I think that an open meeting is not the best place to ask the most damaging of all questions. Then there was the point that innovation seems to require a certain crucial step; most people want to reduce innovation to one step, because then it is easy to understand. All practioners in the field realize that this cannot be done and that innovation is rather a process or a sequence. We referred to the environment within which innovation can take place and then we considered the different types of markets and the tools you can use. In the public market you hope that the opinion tool, which your market analysis is, will be effective. In more sophisticated markets you can use other tools; there is a whole range of technological interest you can arouse by simply waving a new instrument in front of somebody's face. There is also the question of politics and innovation which was not discussed here, but which is related to practical realities, and should be considered by the audience, if not necessarily discussed in public.
At this stage my own analysis of the Conference is that innovation is a matter of attitude more than anything else.
As far as the panel is concerned, we would like to leave it at this. I thank you all for your attention and I hope you did consider it an interesting morning.

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